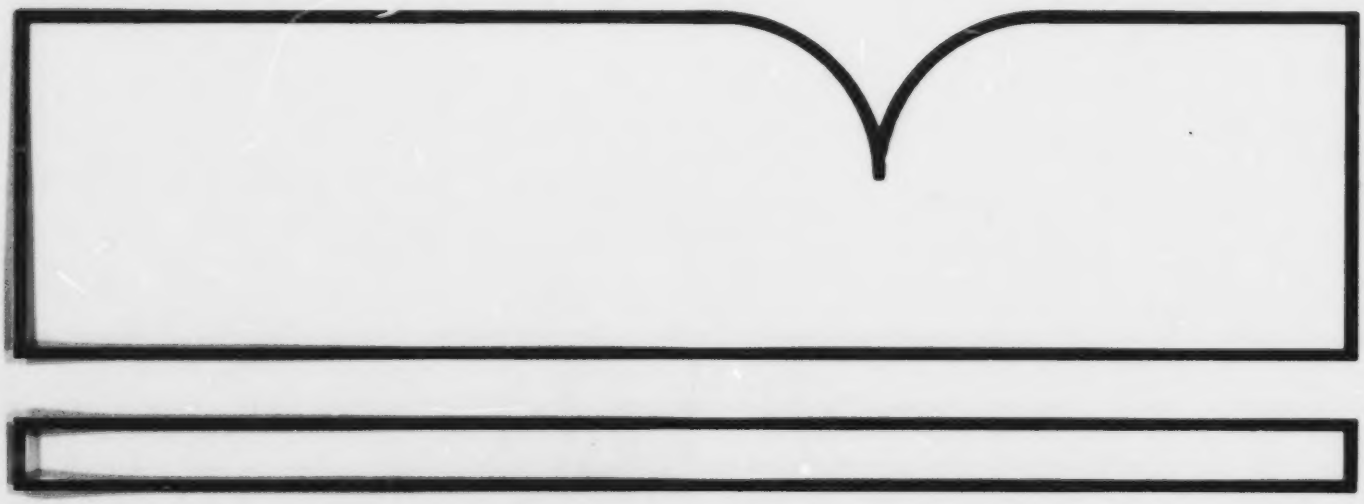
PB81-234759

Fuel Economy Retrofit Devices

(U.S.) Environmental Protection Agency
Ann Arbor, MI

1981



U.S. Department of Commerce
National Technical Information Service

PB81-234759

6560-26

ENVIRONMENTAL PROTECTION AGENCY

[40 CFR Part 610]

[FRL AMS-_____]

FUEL ECONOMY RETROFIT DEVICES

Announcement of Fuel Economy Retrofit Device Evaluation for "GASTELL"

AGENCY: Environmental Protection Agency (EPA).

ACTION: Notice of Fuel Economy Retrofit Device Evaluation.

SUMMARY: This document announces the conclusions of the EPA evaluation of the "Gastell" device under provisions of Section 511 of the Motor Vehicle Information and Cost Savings Act.

REPRODUCED BY
NATIONAL TECHNICAL
INFORMATION SERVICE
U.S. DEPARTMENT OF COMMERCE
SPRINGFIELD, VA 22161

BIBLIOGRAPHIC INFORMATION

PB81-234759

*Fuel Economy Retrofit Devices.

1981

PERFORMER: Environmental Protection Agency, Ann Arbor, MI. Emission Control Technology Div.

See also repot dated Feb 81, PB81-215899.

This document announces the conclusions of the EPA evaluation of the 'Gastel' device under provisions of Section 511 of the Motor Vehicle Information and Cost Savings Act. On November 11, 1979, the EPA received a request from Automotive Devices, Inc. for evaluation of a fuel saving device termed 'Gastell.' This Device is designed to provide the vehicle operator visual and audible indications of inefficient engine operating conditions so that the fuel-conscious drivers can modify their driving habits to obtain improved efficiency. An evaluation has been made and the results are described.

KEYWORDS: *Automobiles, *Fuel consumption.

Available from the National Technical Information Service, Springfield, Va. 22161

PRICE CODE: PC A05/MF A01

BACKGROUND INFORMATION: Section 511(b)(1) and Section 511(c) of the Motor Vehicle Information and Cost Savings Act (15 U.S.C. 2011(b)) requires that:

(b)(1) "Upon application of any manufacturer of a retrofit device (or prototype thereof), upon the request of the Federal Trade Commission pursuant to subsection (a), or upon his own motion, the EPA Administrator shall evaluate, in accordance with rules prescribed under subsection (d), any retrofit device to determine whether the retrofit device increases fuel economy and to determine whether the representations (if any) made with respect to such retrofit devices are accurate."

(c) "The EPA Administrator shall publish in the Federal Register a summary of the results of all tests conducted under this section, together with the EPA Administrator's conclusions as to -

(1) the effect of any retrofit device on fuel economy;

(2) the effect of any such device on emissions of air pollutants; and

(3) any other information which the Administrator determines to be relevant in evaluating such device."

EPA published final regulations establishing procedures for conducting fuel economy retrofit device evaluations on March 23, 1979 [44 FR 17946].

Preceding page blank

ORIGIN OF REQUEST FOR EVALUATION - On November 11, 1979, the EPA received a request from Automotive Devices, Inc. for evaluation of a fuel saving device termed "Gastell." This Device is designed to provide the vehicle operator visual and audible indications of inefficient engine operating conditions so that the fuel-conscious drivers can modify their driving habits to obtain improved efficiency. An evaluation has been made and the results are described completely in a report entitled: "EPA Evaluation of the Gastell Device under Section 511 of the Motor Vehicle Information and Cost Savings Act." Copies of this report are available upon request.

Availability of Evaluation Report: An evaluation has been made and the results are described completely in a report entitled: EPA Evaluation of the Gastell Device under Section 511 of the Motor Vehicle Information and Cost Savings Act," report number EPA-AA-TEB-511-81-8 consisting of 108 pages including all attachments.

EPA also tested the Gastell device. The EPA testing is described completely in the report "Evaluation of Gastell, a Device to Modify Driving Habits," EPA-AA-TEB-81-13, consisting of 47 pages. This report is contained in the preceding Gastell 511 Evaluation as an attachment.

Copies of these reports may be obtained from the National Technical Information Center by using the above report numbers. Address requests to:

The more aggressive (greater acceleration rates) modifications of the LA-4 cycle developed showed little or no change in fuel economy when compared to the standard FTP (LA-4). Therefore, since the preceding tests with the Gastell device did not show an improvement in the vehicles' fuel economy for either the FTP or HFET, the Gastell device was not tested with these more aggressive driving cycles.

Evaluation of five vehicles on a test cycle consisting predominately of accelerations did show that during acceleration there was an average 14.6% improvement in fuel economy between a very low acceleration rate (1 mph/sec.) and the highest acceleration rates used (up to 5 mph/sec.). There was an average 8.5% improvement in fuel economy between the moderate (2 mph/sec.) and highest acceleration rates. This indicates that reduced vehicle acceleration rates can improve fuel economy for some vehicle operation conditions. However, when these acceleration fuel economy improvements are adjusted for the average portion of driving time actually devoted to acceleration, the maximum fuel economy savings would be 1.9%; but, in consideration of the constraints of actual driving, a more realistic potential saving would be less than 0.5%. A similar analysis based on fuel consumed during acceleration modes yielded an average estimated improvement potential of 1.3.

C. Having found no appreciable fuel economy effects in Phases I and II using the vehicle dynamometer, a road test program, Phase III, was undertaken with the Gastell device. For the six combinations of vehicle and operator, in only one case did the use of the Gastell device cause an improvement in vehicle fuel economy greater than 1%. The amount of fuel economy improvement for this one case was 5% with the Gastell device. It is interesting to note that even for this one case, the other less aggressive driver's fuel economy in this vehicle was the same with or without the Device and 4% better than the driver who showed an improvement.

In general, the EPA testing of the Gastell device did not show a positive benefit from its use. None of the Phase I chassis dynamometer tests with the Device installed showed a positive fuel economy effect. Four vehicles of varying size and power-to-weight ratio were road tested in San Antonio (with from one to two drivers each) and only one vehicle/driver combination showed a fuel economy improvement (5%) with the Gastell device. It is concluded from the test data available that only drivers with aggressive driving behavior (or other driving habits that involve excessive throttle manipulation) could benefit from use of this Device and then only if: (1) their vehicle happened to have the fuel economy response characteristics that favorably matched the activation setting of the Device and (2) the driver consistently responded to the Device's signal and refrained from such aggressive driving.

Intuitively, many people might expect the principles behind the Gastell device to produce an improvement in fuel economy. In fact, at the beginning of the program, EPA evaluation engineers involved in the evaluation expected the device to produce significant benefits and were surprised when the early data showed no effect on fuel economy. This evaluation has been more extensive than most such projects at EPA, but as a result, we are comfortable in supporting this evaluation.

FOR FURTHER INFORMATION CONTACT: Merrill W. Korth, Emission Control Technology Division, Office of Mobile Source Air Pollution Control, Environmental Protection Agency, 2565 Plymouth Road, Ann Arbor, Michigan 48105, 313-668-4299.

Date

Edward F. Tuerk
Acting Assistant Administrator
for Air, Noise, and Radiation

EPA Evaluation of the Gastell Device under Section 511 of the Motor Vehicle Information and Cost Savings Act

The following is a summary of the information on the device as supplied by the Applicant and the resulting EPA analysis and conclusions.

1. Marketing Identification of the Device:

"The trade name of the device is GASTELL". "There are four different models available, marked:

2004 four cylinder engines
2005 five cylinder engines
2006 six cylinder engines
2008 eight cylinder engines

Also, if the letter (S) follows the model number, switch is provided to shut off the audible signal; this is optional only."

2. Inventor of the Device and Patents:

Inventor

A. Raymond P. Smith Jr.
2521 Linn Street
Williamsport, PA 17701

Patent

B. "Patents are pending on the device, application is considered to be confidential until patent issues, I have enclosed a copy of this application marked "Priviledged and Confidential." "

3. Manufacturer of the Device:

Automotive Devices, Inc.
129 Susquehanna Street
Williamsport, PA 17701

4. Manufacturing Organization Principals:

Ray P. Smith Jr., President
Robert Flemming, Secretary-Treasurer

5. Marketing Organization in U. S.:

For catalogue sales:
Sun Hill Industries
Glenbrook Industrial Park
652 Glenbrook Rd.
Stamford, CT 06906

All other distributing and marketing by the manufacturer:
Automotive Devices, Inc.
129 Susquehanna Street
Williamsport, PA 17701

"We sell to department stores, automotive warehouses, garages, etc."

6. Marketing Organization in U.S. making Application:

Automotive Devices, Inc.
129 Susquehanna Street
Williamsport, PA 17701

7. Applying Organization Principals:

Ray P. Smith, Jr., President
Robert A. Flemming, Secretary-Treasurer

8. Description of Device:

A. "Purpose of the Device (as supplied by Applicant):

(1). "To provide my energy-starved nation with a product that can assist in the effort to conserve gasoline. For the fuel conscious driver, GASTELL is a constant and reliable source of fuel conserving information. The device will teach any driver on an ongoing basis how to apply proper acceleration of a vehicle with the gasoline internal combustion engine, and obtain top efficiency"

(2). "My second objective of course, is to secure an income through the sale and use of GASTELL."

B. Theory of Operation (as supplied by Applicant):

(1). "GASTELL uses the theory that maintaining the vacuum within the intake manifold of the gasoline internal combustion engine, at sufficient levels will enable a driver to obtain better mileage."

(2). "In operation, GASTELL measures the vacuum within the intake manifold, and converts those readings into audible and visual indicators. The audible indicator is seen to have an advantage over the common vacuum gauge in that (1) you do not have to take your eyes from the road to read its signals and; (2) you don't have to be an engineer to interpret its signals. See Patent Application enclosed, defining operation in detail as well as schematics, defining different methods of construction, and lastly, see the spec sheet." The patent application is Attachment A.

9. Applicability of the Device (as supplied by Applicant):

"GASTELL can be installed on all cars and trucks, regardless of models, with gasoline internal combustion engines.

There are presently four models available.

The 2004 application for 4 cylinder engines
The 2005 application for 5 cylinder engines
The 2006 application for 6 cylinder engines
The 2008 application for 8 cylinder engines

The present calibration settings are: 4 cyls. 3.5 inches of mercury; 5 cyls. 4.0 inches; 6 cyls. 5.0 inches, V-8's 7.0 inches. Some cars and trucks will allow or require slightly higher or lower settings, we suggest the vehicle owner contact dealer or factory, if the unit is too sensitive or not sensitive enough. There is no difference between any models except for calibration. Therefore, any unit can be recalibrated to a different cylinder engine."

10. Costs (as supplied by Applicant):

"The suggested retail price of GASTELL is $39.00. The installation cost should be under $10.00."

11. Device Installation - Tools and Expertise Required (as supplied by Applicant):

"Installation instructions for GASTELL are enclosed." See Attachment B.

12. Device Operation (as supplied by Applicant):

"Operator's Manual enclosed with application." See Attachment B.

13. Maintenance (claimed):

"There are no maintenance procedures required. GASTELL can be calibrated to be more or less sensitive for different engines or vehicles."

14. Effects on Vehicle Emissions (non-regulated) (claimed):

"With the use of GASTELL, the average driver will reduce emission considerably because they are burning up the fuel consumed to a greater extent. I have no scientific fact to substantiate this claim, however, after just a few days of driving with GASTELL, the inside of the tailpipe on the vehicle will turn from black to white. It is concluded from this, that the polluted emissions are reduced significantly from that of the automobile without the device."

15. Effects on Vehicle Safety (claimed):

"GASTELL" can in no way endanger the driver or occupant of a vehicle in use. The device will make a car safer in driving, in that the driver's eyes never have to leave the road to use same. Computers, Flow Scan, and other competing devices all distract the operator from his normal driving, and are a safety hazard in use."

16. Test Results (Regulated Emissions and Fuel Economy) (claimed):

"..... the GASTELL principal is a proven concept. The theory behind it has been tested by our own Government. (See Entitled Driver Aid and Education Project, prepared by the United States Department of Energy, wherein extensive studies were done and have established that a manifold vacuum gauge can improve mileage statistically. (See Page XIV of that report.)" DOE/CS-0043, UC-96, July 1978 "Further, on page XX of the report, last paragraph, the suggestion that a device like GASTELL should be developed and would be an improvement over the common vacuum gauge, in fact would eliminate most of the educational problems experienced with the use of a vacuum gauge, throughout this report. GASTELL, when installed in a car and used properly, would eliminate programs needed to teach people how to use a vacuum gauge. It also would eliminate the need to train over 100 million people in a different method of driving. GASTELL takes the guesswork out of what is too much acceleration when starting out and what is not enough. No two cars are alike." Page XIV is Attachment J-1, Page xx is Attachment J-2.

"Finally, both Automotive Devices and myself have contacted many testing laboratories to attempt to have GASTELL tested. Most have flatly turned us down with reluctance in giving us this in writing. They are all concerned about an area that Government has already clouded the water. A copy of a letter from one of those testing laboratories is enclosed." See Attachment C.

17. Testing by EPA:

A detailed report of the testing performed by the EPA is given in EPA report, EPA-AA-TEB-81-13, "Evaluation of Gastell, A Device to Modify Driving Habits," provided as Attachment B. The test program was conducted over an extended time period and consisted of two dynamometer test phases followed by a road test phase. A brief description of this testing effort is given below:

A. In Phase I, chassis dynamometer tests were conducted according to the Federal Test Procedure (FTP) and the Highway Fuel Economy Test Procedure (HFET). The test program consisted of baseline tests and Gastell tests. The Gastell tests consisted of a standard test procedure (FTP or HFET) which was altered by having the operator back off the accelerator, as necessary, to silence the audible and visual Gastell vacuum alarms. The vehicles tested were:

(1). A 1979 Buick Regal was tested using the procedures cited in 17. A. above. A total of four FTP's and four HFET's were used for this evaluation. Five Hot Start LA-4 tests (first 1372 seconds of the FTP starting with a warmed-up stabilized vehicle) were also conducted using the

baseline, Gastell,and a Gastell "modified"(1). These test data are detailed in Attachment B.

(2). A 1979 Chevrolet Impala was tested using the procedures cited in 17. A. above. A total of five FTP's and six HFET's were used for this evaluation. These test data are detailed in Attachment B.

(3). A 1975 Dodge Dart was tested using the procedures cited in 17. A. above and the Gastell (frozen)(2). A total of six FTP's and six HFET's were used for this evaluation. These test data are detailed in Attachment B.

B. The Phase II testing consisted of modified LA-4's (FTP) and acceleration rate studies conducted on the vehicle chassis dynamometer without using the Gastell device. The testing performed and vehicles used were:

(1) Two more aggressive (greater acceleration rates)(3) driving cycles were developed to further aid in evaluating the Device. The test program consisted of hot start LA-4 tests using the standard driving cycle and these two "new" cycles(3). A total of nine LA-4 tests were conducted on a 1980 Chevrolet Citation. A total of three FTP tests were conducted on a 1975 Chevrolet Nova. These test data are detailed in Attachment B.

(2) A 1980 Chevrolet Citation, 1980 Dodge Aspen, 1979 Ford Pinto, 1979 Mercury Zephyr and a 1979 Oldsmobile Cutlass were used in a test program designed to quantify the effects of acceleration rate on vehicle fuel economy. The test cycles used consisted of a series of accelerations. For these tests, the vehicles were accelerated at a fixed rate to a cruise speed, cruised for a few seconds, and then decelerated at the fixed rate of 2 mph/sec. The cruise time was chosen so that all tests to a selected cruise speed would be of equal distance. This sequence was repeated 4

---

(1) A second Gastell procedure, "modified" was also used. For this procedure the FTP (LA-4) driving cycle was modified by reducing the vehicle accleration rate to a level just below that at which the Device would signal. This smoothed the cycle and would be representative of a very experienced driver's use of the Device.

(2) A third Gastell procedure, "frozen accelerator" was also used. For this procedure the operator again backed off the accelerator to shut off the Gastell alarms. The operator then held his foot fixed in this position until the vehicle's speed matched the driving cycle.

(3) The LA-4 cycle was modified by increasing the acceleration rates at speeds below 25 mph. Two cycles were used - Mod. 1 which used slightly increased acceleration rates and Mod. 2 which used nearly wide-open throttle (WOT) accelerations.

times (5 total cycles). This test sequence was repeated for each combination of acceleration rate and final cruise speed (14 total test sequences) for each vehicle.

C. The third test phase consisted of road tests with the Gastell device under carefully controlled test conditions. Two drivers drove the four test vehicles over a specified road route in San Antonio. The vehicles were:

A 1980 Chevrolet Citation, 1975 Chevrolet Nova, a 1980 Mercury Cougar XR-7, and a 1979 Mercury Marquis were used in the San Antonio road test program. A total of two hundred and thirty road tests were conducted using these vehicles.

18. Analysis

A. Description of the Device:

(1). The primary purpose of GASTELL (as stated in 8. A. 1.), is to save fuel. The operator's manual (see Attachment B), GASTELL sales literature provided with the application (see Attachment D), and ADI's GASTELL information letter provided to EPA (see Attachment E) also state that by functioning as a preset manifold vacuum gauge, GASTELL is able to warn the fuel conscious operator of potential vehicle problems. Insofar as it functions as a preset indicator of manifold vacuum and thereby as a vacuum gauge, this claimed ability to point to problems appears reasonable.

(2). The theory of operation given in 8. B. is in agreement with the functions the device described in the patent application (see Attachment B) would be able to provide -- namely audible and visual indications of vacuum levels above or below a preset level.

(3). The GASTELL device was not described in detail in the application itself. The Device was described in more detail in the sales literature for the device as marketed (see Attachment E) and the patent application. (See Attachment A).

(4). The patent application describes a device incorporating several features not incorporated in the units described in the installation instructions (see Attachment B) and operator's manual (see Attachment B), sales literature (see Attachment D), and GASTELL packaging carton (see Attachment E). These features/functions were:

(a). "a time delay circuit between the alarm circuit and the audio signal generator prevents the audio alarm from being prematurely actuated during necessary periods of inefficient fuel usage, such as those which occur during the emergency handling of the motor vehicle."

(b). an automatic throttle control "connected to the time delay circuit of the alarm circuit, so that the throttle control, like the audio alarm generator, becomes actuated

only if the inefficient fuel consumption condition last beyond a preset amount of time."

(c). a switch to override the throttle control by means of "a microswitch mounted under the gas pedal for breaking the connection between the relay and the time delay circuit when the gas pedal is pressed to the floor of the motor vehicle."

(d). "an electronic counter may be connected to the time delay circuit of the alarm circuit for counting and displaying the number of times a gas wastage condition occured which lasted beyond the preset delay period of the time delay circuit."

The lack of these features/functions was judged to have no material adverse bearing on the GASTELL testing conducted by EPA.

B. Applicability of the Device:

The applicability of the Device stated in the Application (Section 9) appears to be correct for most gasoline engines. However, turbocharged gasoline engines are not specifically addressed. Turbocharged gasoline engines have different manifold vacuum characteristics from their naturally aspirated counterparts and therefore would require a different calibration.

Section 9 also notes that some vehicles will require the Gastell device to be recalibrated to adjust its sensitivity. Although no instructions are given for recalibration it appears to be a straightforward procedure for someone who understands the principal of operation, knows the amount of change required, and has the necessary tools.

C. Costs:

The Device installation appears simple and should be able to be accomplished in a minimum amount of time. The installation cost estimate of $10 appears reasonable for those purchasers who do not choose to install the Device themselves.

D. Device Installation - Tools and Expertise Required:

The GASTELL instructions (see Attachment B) appear to be complete for the physical installation of the Device.

These instructions imply that installation is a do-it-yourself job. The sales literature (Attachment D) says it is a "do-it-yourself installation." The carton (see Attachment E) in which the Device is sold says that the "detailed instructions enclosed with GASTELL allow most drivers to make installaton without professional help." These statements, implied and specified about the level of expertise required for device installation, appear to be correct.

The installation instructions specify only common tools (drill, knife, pliers, and screwdriver) are required for installation. These tool requirements appear to be correct.

The packaging carton states "GASTELL is available in four models. Each is "pre-set" to perform effectively in the engine indicated. It is important to match the correct GASTELL model to the number of cylinders in your engine. No adjustment of GASTELL is necessary." Section 9 notes that the calibration settings may require changes on some vehicles and suggests contacting the dealer or factory. However, there is no reference to the possible need for adjustement of the Gastell calibration given in the installation instructions.

As noted in 18. B., EPA anticipates recalibration should be a straight forward procedure, however it would require some expertise and special tools. Specifically:

(1). understanding the Gastell principal of operation and how the Device was constructed to put this theory into practice

(2). data or factory recommendations as to the necessary amount of change in the calibration required for each model for each condition (too sensitive or not sensitive enough). This information was not provided in the application nor in any of the ADI/GASTELL literature.

(3). vacuum gauge, vacuum source (if vehicle's vacuum source is unable to be used), ohmmeter or voltmeter (if unit is not hooked up to vehicle's 12 volt power).

E. Device Operation:

The Gastell device appears to function as described in 8. B. (2). That is, it converts a vacuum level to an audible and visual signal of that vacuum level. The Device appears to be calibrated to the vacuum levels specified in 9. (see Attachment B, Discussion of Results, 4. Post-Test Gastell Checkout).

The operator's manual (see Attachment B) appears to properly cover the operator's use of the device. However, like the installation instructions (see Attachment B), and packaging (see Attachment E), the operator's manual makes no reference to the possible requirement for recalibration that might be required (see Section 9) to change the Device's sensitivity.

F. Device Maintenance:

The application specifies that no maintenance is required for the Gastell device. Although this appears true in the general usage of the word maintenance, the vacuum lines, electrical lines, and fittings installed would require normally the periodic, albeit infrequent, inspection accorded similiar components in the vehicle.

The application also again notes that the Device can be recalibrated. See 18. D. for discussion.

G. Effects on Vehicle Emissions (non-regulated):

Non-regulated emissions were not assessed as part of this evaluation. However, since the Device 1) does not modify the vehicle's emission control system or powertrain, 2) did not significantly change the test vehicles' fuel economy or emissions (see Attachment B), it appears reasonable to assume that the device would not significantly affect a vehicle's non-regulated emissions.

H. Effects on Vehicle Safety:

When properly installed, it appears unlikely that the Device would adversely affect vehicle safety. Also, the Applicant's claim "that the driver's eyes never have to leave the road to use same" is judged to be correct.

I. Test Results Supplied by Applicant:

Applicant did not submit any test data per the Federal Test Procedure or Highway Fuel Economy Test. These are the only EPA recognized test procedures(4). This requirement for test data following these procedures is stated in the application test policy documents that EPA sends to potential applicants. The test data submitted by the Applicant are listed below and evaluated.

---

(4) From EPA 511 Application test policy documents:

Test Results (Regulated Emissions and Fuel Economy):
Provide all test information which is available on the effects of the device on vehicle emissions and fuel economy.

The Federal Test Procedure (40 CFR Part 86) is the only test which is recognized by the U.S. Environmental Protection Agency for the evaluation of vehicle emissions. The Federal Test Procedure and the Highway Fuel Economy Test (40 CFR Part 600) are the only tests which are normally recognized by the U.S. EPA for evaluating vehicle fuel economy. Data which have been collected in accordance with other standardized fuel economy measuring procedures (e.g. Society of Automotive Engineers) are acceptable as supplemental data to the Federal Test Procedure and Highway Fuel Economy Data will be used, if provided, in the preliminary evaluation of the device. Data are required from the test vehicle(s) in both baseline (all parameters set to manufacturer's specifications) and modified forms (with device installed).

(a). The Applicant stated "The GASTELL is a proven concept. The theory behind it has been tested by our own government" and refers to report "Driver Education and Test Project." DOE/CS-0043.

(i). as noted by the Applicant this report does not test GASTELL but only vacuum gauges.

(ii). the data shows a significant shift in fuel economy for all test vehicles (control, operator trained, and vacuum gauge aided) as soon as the testing with the driving aids was initiated. The cause in the shift for the control group is not explained nor discernable from the data.

(iii). the data report notes that there is less confidence in the urban (city segment) than there is in the highway segment.

(iv). the analysis in the report shows that the conclusions are very sensitive to the method of analysis, i.e. for control group 1, highway segment, the piston vacuum guage shows a 3.7% improvement over the control fleet when average group fuel economy is compared. But tne same data shows 0.0% improvement if fuel weighted average group fuel economy is compared(5).

(v). the largest fuel economy required a gauge plus formal driver training (2 hours classroom plus 2 hours vehicle training).

(vi). the report notes "that while the test results support the hypothesis that use of driver energy conservation training and/or use of a vacuum gauge can result in meaningful improvements in fuel economy, these findings do not conclusively prove that such a relationship exists. While such a relationship appears to have existed in the test under consideration the results obtained do not warrant generalization to all fleets and all driving conditions."

(vii). therefore the above report does not prove nor disprove the Gastell concept or the amount of any fuel economy benefit.

(b). A letter from the National Bureau of Standards (NBS) (Attachment C) summarizes the NBS evaluation of the Gastell invention.

---

(5) "Average Group fuel economy assumes that each monthly vehicle fuel economy reading (monthly miles/monthly gallons) is equally important. Fuel Weighted Average Group Fuel economy assumes that each gallon of fuel is equally important."

(i). The letter states that "Manifold vacuum is a recognized reliable measure for indicating engine operation efficiency. Devices to enable drivers to make beneficial use of the measure have been, as you know, on the market for a long time. Such devices can certainly be of significant value in enabling motivated drivers to reduce fuel usage by increasing operating efficiency."

".... this letter will attest to our opinion that your device is technically sound and commercially competitive, and that its installation and use in automobiles can lead to significant fuel savings by drivers of such vehicles."

(ii). This NBS testimony provides no data nor analysis to support the claims that drivers can expect to obtain increased fuel economy with the aid of manifold vacuum devices. Also there is no reference to the operating conditions or test procedures for which these claims are made.

(iii). Therefore, this letter does not provide information with which to evaluate the effectiveness of GASTELL.

(c). Six testimonial letters (Attachments G-1 thru G-6) were submitted with the application. The writers undoubtedly felt they had achieved significant fuel economy benefits with Gastell. However, these were uncontrolled tests of the Device and therefore cannot be used to evaluate the Gastell device.

(d). A set of data dated 11/12/79 (Attachment H) was also submitted with the application. Some of these tests do show an improvement in fuel economy and the Applicant apparently was able to control some of the test variables. However, these are still relatively uncontrolled tests and therefore cannot be used to evaluate the Gastell Device.

(e). Two additional letters (Attachments I-1, I-2) were also submitted with the application which were not applicable to this evaluation.

J. Test Results Obtained by EPA:

The tests conducted by EPA are discussed in detail in Attachment B. The test program was conducted over an extended time period and consisted of two dynamometer test phases followed by a road test phase. The testing performed by EPA showed:

(1). The Phase I testing consisted of FTP and HFET dynamometer tests of the Gastell device. Overall, the use of the Gastell device as a driving aid did not show a significant effect on the vehicle's fuel economy or emissions for either the FTP or HFET.

(2). The Phase II testing consisted of modified LA-4's (FTP) and acceleration rate studies conducted on the vehicle chassis dynamometer without using the Gastell device.

The more aggressive (greater acceleration rates) modifications of the LA-4 cycle developed showed little or no change in fuel economy when compared to the standard FTP (LA-4). Therefore, since the preceding tests with the Gastell device did not show an improvement in the vehicles' fuel economy for either the FTP or HFET, the Gastell device was not tested with these more agressive driving cycles.

Evaluation of five vehicles on a test cycle consisting predominately of accelerations did show that during acceleration there was an average 14.6% improvement in fuel economy between a very low acceleration rate (1 mph/sec.) and the highest acceleration rates used (up to 5 mph/sec.). There was an average 8.5% improvement in fuel economy between the moderate (2 mph/sec) and highest acceleration rates. This indicates that reduced vehicle acceleration rates can improve fuel economy for some vehicle operating conditions. However, when these acceleration fuel economy improvements are adjusted for the average portion of driving time actually devoted to acceleration, the maximum fuel economy savings would be 1.9%; but, in consideration of the constraints of actual driving conditions, a more realistic potential saving would be less than 1/2%. A similar analysis based on fuel consumed during acceleration modes yielded an average estimated improvement potential of 1.3%.

(3). Having found no appreciable fuel economy effects in Phases I and II using the vehicle dynamometer, a road test program, Phase III, was undertaken with the Gastell device. For the six combinations of vehicle and operator, in only one case did the use of the Gastell device cause an improvement in vehicle fuel economy greater than 1%. The amount of fuel economy improvement for this one case was 5%. It is interesting to note that even for this one case, the other less aggressive driver's fuel economy in this vehicle was the same with or without the Device and 4% better than the driver who showed an improvement.

19. Conclusions

EPA fully considered all of the information submitted by the Device manufacturer in the Application. The evaluation of the Gastell device was based on that information and the results of the EPA test program. In general, the EPA testing of the Gastell device did not show a positive benefit from its use. None of the Phase I chassis dynamometer tests with the Device installed showed a positive fuel economy effect. Four vehicles of varying size and power-to-weight ratio were road tested in San Antonio (with from one to two drivers

each) and only one vehicle/driver combination showed a fuel economy improvement (5%) with the Gastell device. It is concluded from the test data available that only drivers with aggressive driving behavior (or other driving habits that involve excessive throttle manipulation) could benefit from use of this Device and then only if; (1) their vehicle happened to have the fuel economy response characteristics that favorably matched the activation setting of the Device and (2) the driver consistently responded to the device signal and refrained from such aggressive driving.

Intuitively, many people might expect the principles behind the Gastell device to produce an improvement in fuel economy. In fact, at the beginning of the program, EPA evaluation engineers involved in the evaluation expected the device to produce significant benefits and were surprised when the early data showed no effect on fuel economy. This evaluation has been more extensive than most such projects at EPA, but as a result, we are comfortable in supporting this evaluation.

List of Attachments

Attachment A	Patent Application (provided with 511 Application)
Attachment B	TEB Report EPA-AA-TEB-81-13, "Evaluation of Gastell, A Device to Modify Driving Habits"
Attachment C	Letter dated October 29, 1979 from National Bureau of Standards to Mr. Ray P. Smith, Jr. (provided with 511 application)
Attachemnt D	Gastell Sales Literature (provided with 511 application)
Attachment E	Copy of GASTELL Packaging Carton
Attachment F	Automotive Devices Inc. Information Letter
Attachment G-1 thru G-6	Gastell Testimonial Letters (provided with 511 application)
Attachment H	Gastell testing conducted on 11/12/79 (provided in 511 application)
Attachments I-1, I-2	Letters provided with 511 application that were not pertinent to evaluation
Operators Manual	Provided in 511 application, copy incorporated in Attachment B
Installation Instructions	Provided in 511 application, copy incorporated in Attachment B
Attachment J-1	Page XIV of DOE/CS-0043, UC-96, July 1978 (provided with application)
Attachment J-2	Page XX of DOE/CS-0043, UC-96, July 1978 (provided with application)

FUEL CONSUMPTION SIGNALLING SYSTEM

Invented by:

Raymond P. Smith, Jr.

Proprietary to [illegible], shall not be reproduced or copied without written permission nor used in any manner detrimental to its interest and shall be returned upon request.

ABSTRACT OF THE DISCLOSURE

A fuel consumption signalling system for signalling both efficient and inefficient fuel consumption conditions in the engine of a motor vehicle is herein disclosed. The system comprises an alarm circuit connected in series with an indicator circuit including an indicator light connected in parallel with a vacuum operated switch pneumatically connected to the engine manifold. An electric potential sufficient to actuate the alarm circuit, but insufficient to actuate both the indicator light and the alarm circuit is applied across the series connected indicator and alarm circuits. When the engine is consuming fuel efficiently, the vacuum switch is open, and the electric potential is divided between the indicator circuit and the alarm circuit. The divided potential is sufficient to illuminate the indicator light, but insufficient to actuate the alarm circuit. However, when the engine consumes fuel inefficiently, the vacuum switch closes, shunting the entire electric potential across the alarm circuit, thereby actuating it. The signalling system may also include an automatic throttle plate control.

Figure 2

BACKGROUND OF THE INVENTION

In recent years, the rising cost of fuel has sharply increased the need for more efficient consumption of fuel. One well known, but little used method of efficient fuel consumption in a motor vehicle lies in the conscientious use of fuel saving driving techniques. In fact, a 1978 United States government publication entitled "Driver Aid and Education Test Project" (DOE/CS-0043) and prepared for the U.S. Department of Energy states, on page 1, that it is "...not unusual to find a variation of 30 to 50 percent in fuel economy among a group of non-professional drivers operating under identical and controlled test conditions...", the difference being attributable solely to individual driving techniques. Thus, it is clear that significant amounts of fuel could be saved by the widespread adoption of fuel efficient driving techniques by the motor vehicle operators of this country.

To encourage the use of such efficient driving techniques, a variety of fuel consumption gauges and indicators have been provided by the prior art. Such prior art fuel consumption gauges have typically utilized a vacuum operated sensor to monitor the manifold pressure of the engine, as the manifold pressure is one of the best over all indicators of efficient fuel use. A high vacuum pressure in the engine manifold indicates that the fuel is being burned in a fuel to air ratio which results in complete, and hence efficient, combustion. By contrast, a low vacuum pressure in the manifold indicates that the fuel is being burned in an overly rich fuel to air ratio which results in incomplete, and hence inefficient, combustion. In operation, the vacuum operated sensor of

typical prior art devices senses whether the pressure of the engine manifold is in a high or low vacuum state, and transmits this information to an indicator which in turn indicates to the driver whether or not the motor vehicle is being driven in a fuel efficient fashion.

Unfortunately, each of the prior art fuel consumption indicators has, thus far, been attended by a variety of technical drawbacks which in turn has discouraged its general use among the motor vehicle operators of this country. For example, Polymeros patent 2,666,197 discloses a vacuum operated signal device having a vacuum operated switch adapted to be mounted on the instrument panel of an automobile. However, the single pilot light of Polymeros' invention only gives a visual indication of an inefficient fuel consumption condition in the engine which is easily overlooked by a driver observing the road. Further, the suggested location of the single pilot light of this invention between other lights and indicators on the instrument panel of the automobile makes installation difficult, and renders the single pilot light less perceptible to the driver than if the signal light were mounted away from the other lights and dials of the instrument panel. Finally, because the pilot light is actuated only during a fuel wastage condition in the engine, it is difficult to tell at any given time whether or not the invention is operative.

While Corsseu patent 2,683,782, Shuck patent 2,870,753, and Platt patent 2,692,980 each disclose manifold pressure indicators utilizing two separate signalling devices for signalling both efficient and inefficient fuel consumption conditions in an internal combustion engine, they suffer

from the drawback of utilizing relatively intricate and expensive single pole, double throw or double pole vacuum operated switches. Additionally, each of these devices utilizes only a pilot light for indicating an inefficient fuel consumption condition which again can be easily overlooked by an operator with his full attention on the road.

Finally, although the manifold pressure indicator disclosed in Australian patent 114,535 suggests the use of an audio signal to signal an inefficient fuel condition, this device, like the Polymeros invention, is capable of signalling only an inefficient fuel consumption condition. Additionally, no suggestion is made as to how to conveniently mount this device in the cockpit of a conventional motor vehicle.

Clearly the need exists for a conveniently installable, simple, effective and inexpensive fuel consumption signalling system which has at least two separate signalling devices for positively signalling both efficient and inefficient fuel consumption conditions.

SUMMARY OF THE INVENTION

The invention relates to a fuel consumption signalling system which is conveniently installable within a conventional motor vehicle and which has two separate signalling devices for signalling both efficient and inefficient fuel consumption conditions in the engine of a motor vehicle without any of the drawbacks associated with prior art devices of this type. Basically, the signalling system comprises an alarm circuit for indicating an inefficient fuel consumption condition which is connected in series with an indicator circuit for indicating an efficient fuel consumption condition. The alarm circuit includes an alarm light, a resistor, and a time

FIGURE 2

delay circuit having an audio alarm generator, each of which is connected to the other in parallel. The indicator circuit includes an indicator light and a normally open vacuum operated switch connected together in parallel. The vacuum operated switch is pneumatically connected to the engine manifold of the motor vehicle. A source of electrical potential sufficient enough to actuate the alarm circuit, but insufficient to actuate both the alarm circuit and the indicator light of the indicator circuit is applied across the series connected alarm and indicator circuits.

In operation, the vacuum operated switch closes when the manifold pressure attains a value indicative of inefficient fuel consumption, thereby shunting the entire electrical potential around the indicator light and across the alarm circuit. Thus, the indicator light is extinguished and the alarm circuit is actuated, perceptibly illuminating the alarm light and triggering the time delay circuit. If the inefficient fuel consumption condition lasts beyond a preset amount of time, the time delay circuit then actuates an audio alarm generator.

Both the series circuit and the vacuum operated switch are mounted in a box-like housing which is conveniently installable either above or below the instrument panel of a conventional motor vehicle by means of simple brackets.

Thus, the invention provides an easily installable, simple, effective and inexpensive fuel consumption signalling device having two separate indicators for positively signalling both efficient and inefficient fuel consumption conditions in an engine. The use of a simple, single pole, vacuum operated switch in a dual signalling system instead of the intricate and more expensive multipole vacuum switches frequently associated with the prior art devices significantly

Figure 2

reduces costs while increasing reliability. More particularly, the use of a simple, single pole vacuum switch in combination with an indicator light which serves the dual function of indicating a fuel efficient condition while providing a voltage divider along the series circuit constitutes a significant improvement over the prior art, providing maximum of performance with a minimum of parts.

Finally, the use of a time delay circuit between the alarm circuit and the audio signal generator prevents the audio alarm from being prematurely actuated during necessary periods of inefficient fuel usage, such as those which occur during the emergency handling of the motor vehicle.

The fuel consumption signalling system may also include an automatic throttle control for automatically eliminating inefficient fuel consumption condition. The automatic throttle control basically comprises a lever connected to the carburetor throttle blade rod of the motor vehicle engine, and a solenoid having an extensible plunger for limiting the movement of this lever. The solenoid is actuated by a relay connected to the time delay circuit of the alarm circuit, so that the throttle control, like the audio alarm generator, becomes actuated only if the inefficient fuel consumption condition last beyond a preset amount of time.

The system also includes a means for overriding the throttle control including a microswitch mounted under the gas pedal for breaking the connection between the relay and the time delay circuit when the gas pedal is pressed to the floor of the motor vehicle.

Additionally, an electronic counter may be connected to the time delay circuit of the alarm circuit for counting and displaying the number of times a gas wastage condition occured which lasted beyond the preset delay period of the time delay circuit.

BRIEF DESCRIPTION OF THE SEVERAL DRAWINGS

Figure 1 is an electromechanical diagram of the circuit of the fuel consumption signalling system installed in a conventional motor vehicle;

Figure 2 illustrates a cross sectional side view of the vacuum operated switch of the fuel consumption signalling system;

Figure 3 illustrates a cross sectional side view of the microswitch of the throttle control override means as it would appear mounted in a conventional motor vehicle; and

Figure 4 is a schematic of the time delay circuit of the invention.

Figure 2

DETAILED DESCRIPTION OF THE INVENTION

With reference to Figure 1, the system 1 basically comprises an alarm circuit 3 connected in series with an indicator circuit .

The alarm circuit includes an alarm light 5, a resistor 7 and a time delay circuit 9 including an audio alarm generator 10, each of which is connected to the other in parallel as indicated. In the preferred embodiment, alarm light 5 comprises a red GE #18 miniature lamp having an electrical resistance of approximately 30 ohms, resistor 7 has a resistance of approximately 75 ohms, and time delay circuit 9 has a resistance of over 300 ohms, such that the entire alarm circuit has a resistance of about 20 ohms. Time delay circuit 9 serves as a time delay switch delaying the actuation of the audio alarm generator 10, the counter 11 and the throttle plate control 40 for a period of about three seconds to allow for short, necessary periods of fuel wastage, such as might occur in emergency handling situations. Additionally, time delay circuit 9 is preferably adjustable so that drivers driving in hilly terrain or other conditions which regularly demand unusually long periods of gas wastage may adjust the time delay for a period over three seconds. Time delay circuit 9 is described more particularly hereafter. A variety of prior art audio signal generators may comprise the audio signal generator 10 of the invention, such as the Mallory "Son Alert" (part number SC 628) or Edwards "Lumatone" (part number E 101). Finally, a number of prior art electric counters and display devices may likewise comprise the counter 11 of the invention, such as AMP thumbwheel switch number .300 (7.62), which is connected to the time delay circuit 9 and counts and displays the number of fuel wastage occasions lasting longer than the time delay of the time delay circuit 9.

Figure 2

The indicator circuit 15 includes an indicator light 17 connected in parallel to a normally open, vacuum operated switch 20. In the preferred embodiment, indicator light 17 is a green, GE #73 light bulb having a resistance of approximately 30 ohms.

A 12 volt source of potential difference is connected at points 2 and 18 of the series circuit, as shown. In the preferred embodiment this source of potential difference comprises the ignition system of the vehicle, rather than the car battery, so that the system will automatically turn on and off with the engine of the vehicle.

With reference now to Figure 2, the normally open vacuum operated switch 20 of the system 1 includes a housing divided into two noncommunicating pneumatic chambers 28a, 28b by a resilient diaphram 27 as shown. The upper surface of diaphragm 27 is placed in pneumatic communication with the ambient atmosphere by aperture 24. The bottom surface of diaphragm 27 is placed in pneumatic communication with the engine manifold (not shown) by means of a vacuum line 21 terminating in a "T" joint which is preferably conveniently connected to the pneumatic circuit powering the intake manifold of the vehicle, although any point will do. A plunger member 29 having a pair of bimetallic electrical contacts 30a, b is biased against the lower surface of diaphragm 27 by means of coil spring 31. A complementary pair of contacts 33a, b connected in parallel with indicator light 17 is placed above the contacts 30a, b. Adjustment screw 35 balances the spring biasing force exerted on the underside of diaphragm 27 against the pneumatic force exerted on the top surface of diaphragm 27 by the atmosphere. More particularly, the adjustment screw 35 balances the spring and the pneumatic forces so that the contacts 30a, b and 33a, b remain out of conductive

FIGURE 2

engagement when a fuel efficient, high vacuum is present in the manifold, but come together in conductive engagement when a fuel wasting low vacuum is present in the manifold. For a V-8 engine, adjustment screw 35 is adjusted so that the contacts 30a, b and 33a, b do not come into conducting engagement until the manifold pressure falls to about seven inches of mercury. For six and four cylinder cars, the screw is adjusted to a setting corresponding to about six and three and a half inches of mercury, respectively.

In operation, a 12 volt potential difference is connected across the series circuit comprising alarm circuit 3 and indicator circuit 15 at points 2 and 18 when the engine of the vehicle is started.

If the vacuum pressure in the engine manifold is high enough to keep contacts 30a, b and 33a, b from coming into conductive engagement, the 12 volt potential is divided between the indicator light 17 of the indicator circuit 15 and the alarm circuit 3. The divided potential across the indicator light 17 is sufficient to perceptibly illuminate it. By contrast, the potential divided across the alarm circuit 3 is insufficient to either trigger time delay circuit 9, which does not become actuated before a certain threshold voltage is attained, or perceptibly illuminate alarm light 3, due to the effect of resistor 7 in dropping some of the potential across the incandescent element of light 3.

However, if the manifold pressure falls below an appropriate preset value, the contacts 30a, b and 33a, b come into conducting engagement, extinguishing indicator light 17 and shunting the entire potential difference between points 2 and 18 across alarm circuit 3, actuating it. It should be noted in closing that indicator light serves to provide a voltage divider between

Figure 2

the source of electric potential and the alarm circuit 15 so that the latter is not actuated until the engine is operated in a fuel wasteful fashion, as well as an indicator for positively indicating when the vehicle is being operated in a fuel efficient manner. The indicator light 17 also serves as a positive indicator that the invention is functioning properly.

With reference again to Figure 1, the system may also include a throttle plate control 40 comprising a relay 12 which is connected to time delay circuit for actuating a solenoid 42 having a plunger 44 for limiting the motion of a lever connected to the throttle plate rod of the carburetor 50 of the engine of the motor vehicle. The throttle plate control also includes an override control comprised of a microswitch 13 for breaking the electrical connection between relay 12 and time delay circuit 9, which in turn disconnects solenoid 42 from the ignition system of the vehicle, retracting plunger 44 from lever 46 and allowing free movement of the throttle plate 52 of the carburetor 50.

With reference now to Figure 3, microswitch comprises a plunger 60 slidably mounted in a housing 61 having a pair of contacts 62a, b normally biased against a pair of complementary contacts 63a, b by a leaf spring 65. Leaf spring 65 serves to bias contacts 62a, b against complementary contacts 63a, b such that relay 12 is normally electrically connected to time delay circuit 9. Leaf spring 65 also serves to provide an audible and tactile indicator of when the throttle plate control is overriden by providing an audible and tactile "click" when the operator floors gas pedal 70 against plunger 60 of microswitch 13, as is discussed in detail hereafter.

In operation, the throttle plate control 42 is actuated by time delay circuit 9, which closes relay 12 a preset time after alarm circuit 3 is actuated. Relay 12 connects solenoid 42 to

the ignition system of the vehicle, which in turn forcibly extends plunger 44 to a position which limits the movement of lever 46. This action in turn obstructs the carburetor throttle plate from assuming an angular position which would lower the manifold vacuum pressure and result in fuel wastage. If the operator of the vehicle needs to temporarily override the throttle plate control 40, as could occur in emergency driving conditions, the driver floors the gas pedal 70 of the vehicle, thereby depressing plunger 60 into leaf spring 65. The leaf spring 65 yields much the same way the metal blister structure on the bottom of a conventional oil can does, thereby disengaging contacts 62a, b and 63a, b with both an audible and a tactile click. The contact arm of relay 12 returns to its normal position, disconnecting solenoid 42 from the ignition system of the vehicle. Solenoid 42 then retracts plunger 44, which in turn frees lever arm 42.

Referring finally to Figure 4, the time delay circuit 9 of the invention comprises a series connected thermal element 88 and potentiometer 86 which in turn is connected in parallel with the alarm circuit 3 at points 82 and 84. The thermal element 88 regulates switching contact points 89a and 89b. When the alarm circuit is actuated, the thermal element 88 expands after a time delay to lose switching contact points 82 and 84, thereby actuating the audio signal generator 10, the electric counter 11, and throttle plate control relay 12. The duration of the time delay is controlled by potentiometer 86.

All of the aforementioned components of the system, with the exception of the throttle plate control 40 and override switch 13, may be mounted in a single, conveniently installable box-like housing (not shown) which may be attached either on

the top or the bottom of the instrument panel by any suitable means, such as brackets.

Having particularly pointed out my invention in such full, clear, and concise and exact terms as to enable any person skilled in the pertinent art to make and use the same, I claim:

1. A fuel consumption signalling system for signalling both efficient and inefficient fuel consumption conditions in the engine of a motor vehicle, comprising:

(a) an alarm circuit including, connected in parallel, an alarm light and a resistor, said alarm circuit being actuatable by a predetermined potential difference;

(b) an indicator circuit connected to said alarm circuit in series to form a series circuit, said indicator circuit including, connected in parallel,

(i) an indicator light for indicating an efficient operating condition in the motor vehicle engine and for serving as a voltage divider for any potential applied across said series circuit, and

(ii) a vacuum operated, normally open switch pneumatically connected to the engine manifold for shunting any electric potential applied across said indicator lamp around said indicator lamp when the manifold pressure closes said switch, and

(c) means for applying a potential difference across the series circuit, said applied potential being greater than the potential necessary to actuate the alarm circuit when said potential is shunted around the indicator light when the vacuum operated switch is closed, but less than the potential necessary to actuate the alarm circuit when the switch is open and the applied potential is divided between the indicator light and the alarm circuit.

2. The fuel consumption signalling system of claim 1, wherein said alarm circuit further includes, connected in parallel, a time delay circuit for actuating an audio alarm generator a preset time after said alarm circuit is actuated.

3. The fuel consumption signalling system of claim 2 further including a digital counting means connected to said time delay circuit for counting and displaying the number of occasions the engine was run in inefficient fuel consumption condition for a period of time greater than the time delay of said time delay circuit.

4. The fuel consumption signalling system of claim 3 further including a relay connected to the time delay circuit for actuating a throttle plate control a preset time after said alarm circuit is actuated.

5. The fuel consumption signalling system of claim 4, wherein said throttle plate control comprises:

(a) a lever connected to the carburetor throttle blade rod of the engine of the motor vehicle, and

(b) a solenoid actuatable by said relay and having an extensible plunger for limiting the motion of said lever when said solenoid is actuated, whereby the position of the throttle plate is automatically confined to an angular position consistent with efficient fuel consumption a preset time after said alarm circuit is actuated.

6. The fuel consumption signalling system of claim 5, further including means for overriding said throttle plate control including a microswitch mounted under the accelerator pedal of the motor vehicle for electrically disconnecting said relay from said time delay circuit when said accelerator is pressed to the floor of the vehicle,

whereby said extensible solenoid plunger retracts to allow free movement of said lever connected to said throttle plate rod.

FIGURE 2

13. The fuel consumption signalling system of claim 12, further including means for overriding said throttle plate control including a microswitch mounted under the accelerator pedal of the motor vehicle for electrically disconnecting said relay from said time delay circuit when said accelerator is pressed to the floor of the vehicle.

14. The fuel consumption signalling system of claim 13, wherein said microswitch includes a tactile indicating means for indicating when said switch is operated to disconnect said relay from said time delay circuit.

7. The fuel consumption signalling system of claim 6, wherein said microswitch includes a tactile indicating means for indicating when said switch is operated to disconnect said relay from said time delay circuit.

8. The fuel consumption signalling system of claim 7, wherein said time delay circuit is adjustable to actuate said audio alarm generator, said counter, and said throttle plate control at a variety of times after said alarm circuit is actuated.

9. A fuel consumption signalling system for signalling both efficient and inefficient fuel consumption conditions in the engine of a motor vehicle, comprising:

(a) an alarm circuit including, connected in parallel, an alarm light, a resistor, and a time delay circuit having an audio alarm generator, said alarm circuit being actuatable by a predetermined potential difference;

(b) an indicator circuit connected in series with said alarm circuit to form a series circuit, said indicator circuit including, connected in parallel,

(i) an indicator light for indicating an efficient operating condition in the engine of the motor vehicle and for serving as a voltage divider for any potential applied across said series circuit, and

(ii) a vacuum operated, normally open switch pneumatically connected to the engine manifold of the motor vehicle for shunting any electric potential applied across said indicator lamp around said lamp when a predetermined manifold pressure indicative of a fuel waste condition closes said switch, and

FIGURE 2

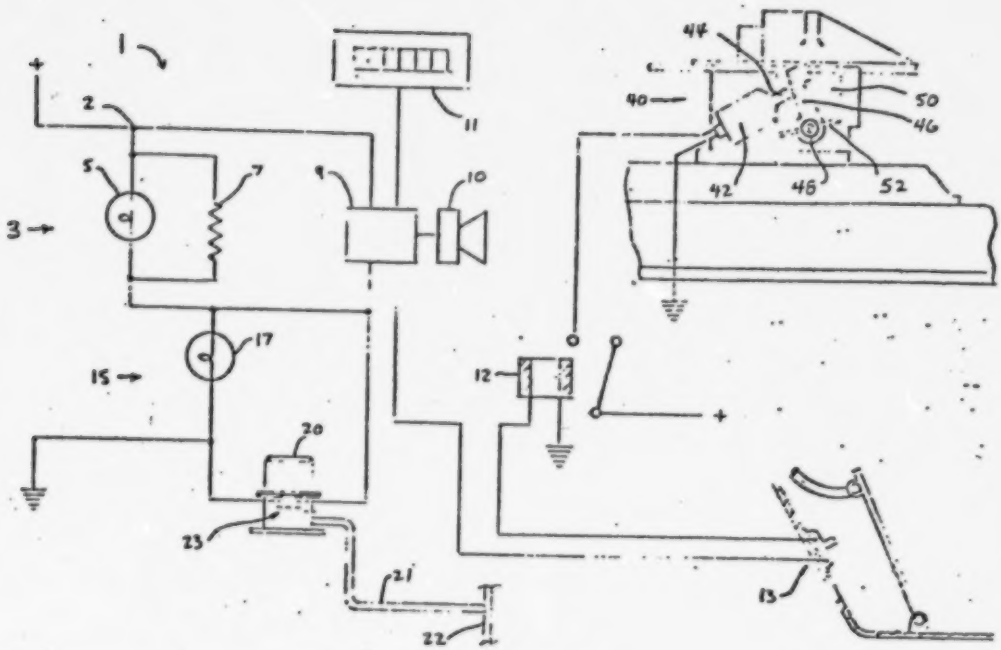


FIGURE 1
Electromechanical Energizer

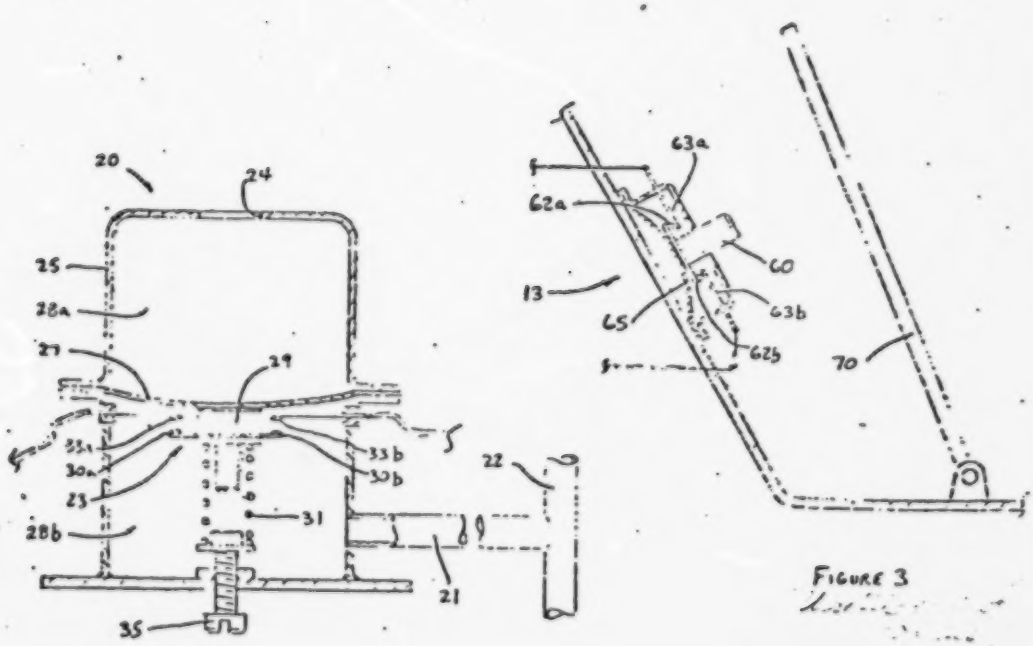


FIGURE 3

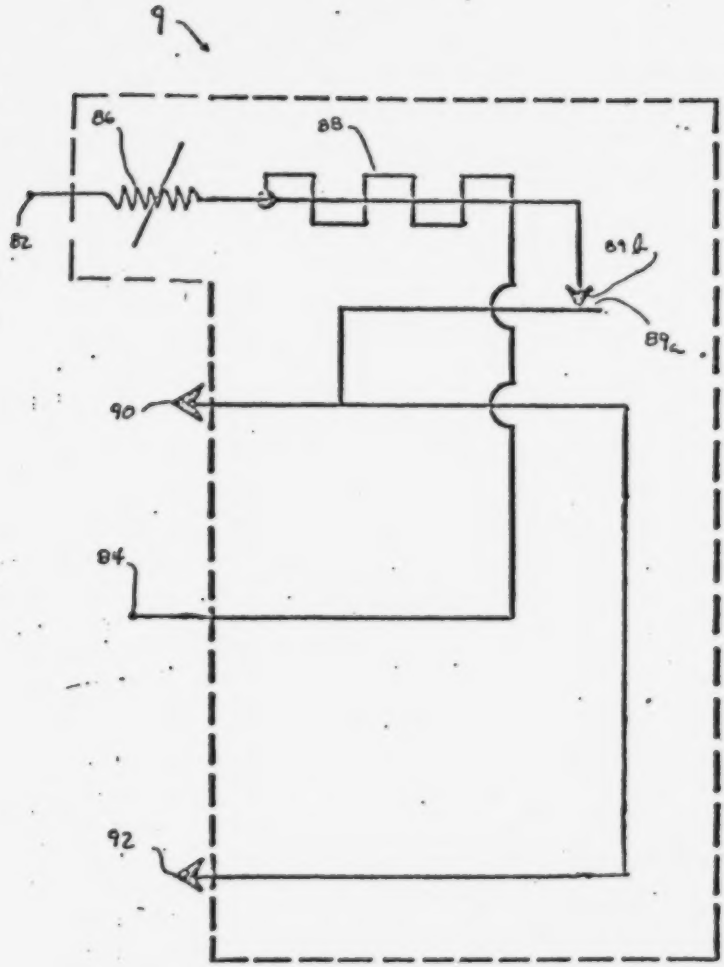


FIGURE 4

COMBINED DECLARATION AND POWER OF ATTORNEY
IN ORIGINAL APPLICATION

ATTORNEY DOCKET NO.

As a below named inventor, I hereby declare that:
my residence, post office address and citizenship are as stated below next to my name; that
I verily believe that I am the original, first and sole inventor (if only one name is listed below) or a joint inventor (if plural inventors are named below) of the invention entitled:

Fuel Consumption Signalling System

described and claimed in the attached specification, that I understand the content of the attached specification, that I do not know and do not believe the same was ever known or used in the United States of America before my or our invention thereof, or patented or described in any printed publication in any country before my or our invention thereof or more than one year prior to this application, that the same was not in public use or on sale in the United States of America more than one year prior to this application, that the invention has not been patented or made the subject of an inventor's certificate issued before the date of this application in any country foreign to the United States of America on an application filed by me or my legal representatives or assigns more than twelve months prior to this application, that I acknowledge my duty to disclose information of which I am aware which is material to the examination of this application, and that no application for patent or inventor's certificate on this invention has been filed in any country foreign to the United States of America prior to this application by me or my legal representatives or assigns, except as follows:

I hereby appoint the following attorney(s) and/or agent(s) to prosecute this application and to transact all business in the Patent and Trademark Office connected therewith: Thomas W. Cole, Reg. #28,290; Donald E. Stout, Reg. #26,422 and James R. Laramie, Reg. #26,934

Address all telephone calls to Thomas W. Cole at telephone no. 202-466-5200
Address all correspondence to Thomas W. Cole, 1801 K St., N.W. Washington, D.C. 20006

I hereby declare that all statements made herein of my own knowledge are true and that all statements made on information and belief are believed to be true; and further that these statements were made with the knowledge that willful false statements and the like so made are punishable by fine or imprisonment, or both, under Section 1001 of Title 18 of the United States Code and that such willful false statements may jeopardize the validity of the application or any patent issued thereon.

FULL NAME OF SOLE OR FIRST INVENTOR	INVENTOR'S SIGNATURE	DATE
Raymond P. Smith, Jr.		
RESIDENCE		CITIZENSHIP
2521 Linn Street, Williamsport, Pennsylvania 17701		U.S.A.
POST OFFICE ADDRESS		
P.O. Box 294, 129 Susquehanna Street, Williamsport, Pennsylvania 17701		
FULL NAME OF SECOND JOINT INVENTOR, IF ANY	INVENTOR'S SIGNATURE	DATE
RESIDENCE		CITIZENSHIP
POST OFFICE ADDRESS		
FULL NAME OF THIRD JOINT INVENTOR, IF ANY	INVENTOR'S SIGNATURE	DATE
RESIDENCE		CITIZENSHIP
POST OFFICE ADDRESS		

FORM PTO-2038 (12-77) Patent & TM Office - U.S. COMM-D.C.

Reproduced from best available copy.

SPECIFICATION

Be it known that, I, Raymond P. Smith, Jr., a citizen of the United States of America, residing at 2521 Linn Street, Williamsport, Pennsylvania 17701, have invented a new, original design for an

AUTOMOTIVE FUEL CONSUMPTION ALARM

of which the following in a specification, reference being had to the accompanying drawings, forming a part hereof.

Fig. 1 in a front perspective view of an automotive fuel consumption alarm showing my new design;

Fig. 2 is a front elevation thereof;

Fig. 3 is a top plan thereof;

Fig. 4 is a bottom plan thereof;

Fig. 5 is a rear elevation thereof; and

Fig. 6 is a right side elevation thereof.

I claim: The ornamental design for an Automotive Fuel Consumption Alarm as shown.

Raymond P. Smith, Jr.

Proprietary to Crafts... Inc. shall not be reproduced or copied without written permission nor use... detrimental to its interest and ... be returned upon request.

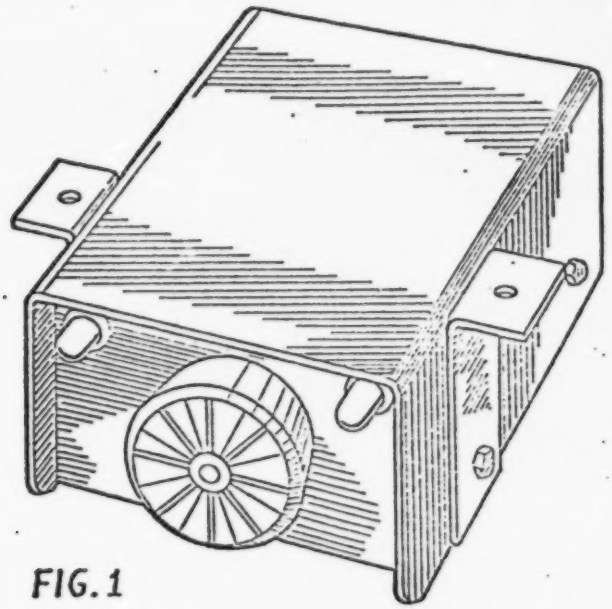


FIG. 1

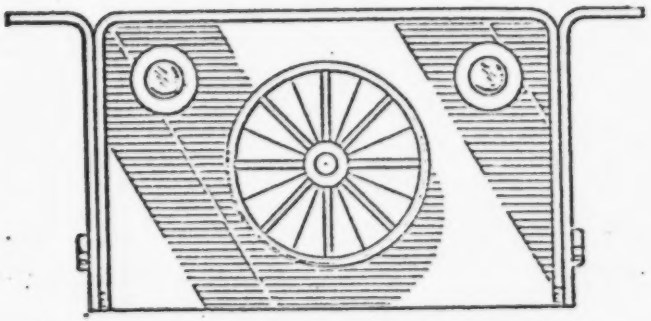


FIG. 2

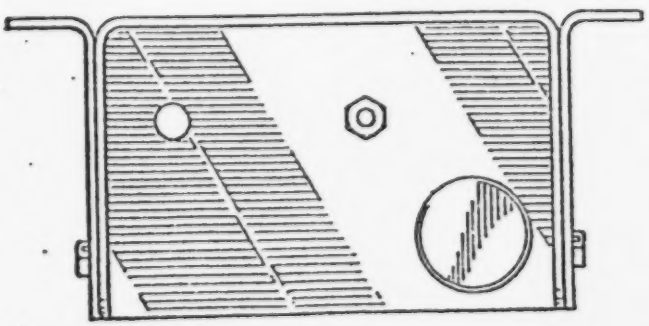


FIG. 5

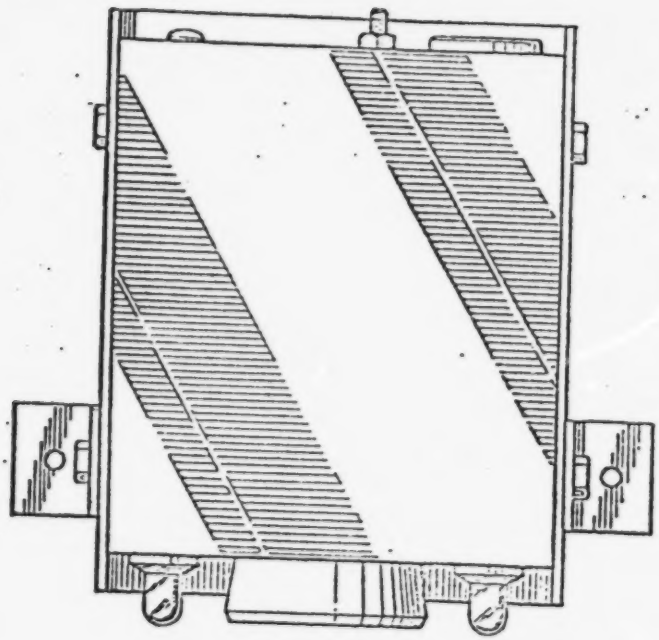


FIG. 4

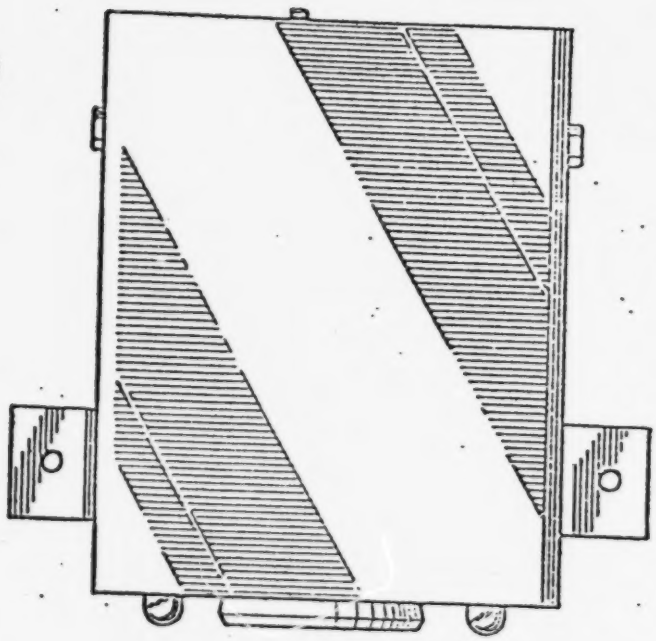


FIG.3

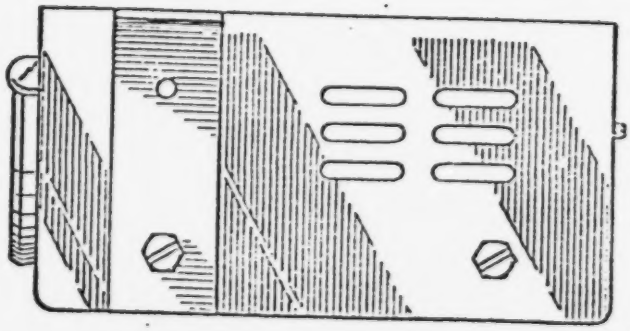


FIG.6

COMBINED DECLARATION AND POWER OF ATTORNEY
IN ORIGINAL APPLICATION

ATTORNEY DOCKET NO.

As a below named inventor, I hereby declare that:
my residence, post office address and citizenship are as stated below next to my name; that
I verily believe that I am the original, first and sole inventor (if only one name is listed below) or a joint inventor (if plural inventors are named below) of the invention entitled: Automotive Fuel Consumption Alarm

described and claimed in the attached specification, that I understand the content of the attached specification, that I do not know and do not believe the same was ever known or used in the United States of America before my or our invention thereof, or patented or described in any printed publication in any country before my or our invention thereof or more than one year prior to this application, that the same was not in public use or on sale in the United States of America more than one year prior to this application, that the invention has not been patented or made the subject of an inventor's certificate issued before the date of this application in any country foreign to the United States of America on an application filed by me or my legal representatives or assigns more than ~~twelve~~ SIX months prior to this application, that I acknowledge my duty to disclose information of which I am aware which is material to the examination of this application, and that no application for patent or inventor's certificate on this invention has been filed in any country foreign to the United States of America prior to this application by me or my legal representatives or assigns, except as follows:

I hereby appoint the following attorney(s) and/or agent(s) to prosecute this application and to transact all business in the Patent and Trademark Office connected therewith: Thomas W. Cole, Reg. No. 26,290; Donald E. Stout, Reg. No. 26,422 and James R. Laramie, Reg. No. 26,934

Address all telephone calls to Thomas W. Cole at telephone no. 202-466-5200
Address all correspondence to Thomas W. Cole, 1801 K St., N.W. Washington, D.C. 20006
I hereby declare that all statements made herein of my own knowledge are true and that all statements made on information and belief are believed to be true; and further that these statements were made with the knowledge that willful false statements and the like so made are punishable by fine or imprisonment, or both, under Section 1001 of Title 18 of the United States Code and that such willful false statements may jeopardize the validity of the application or any patent issued thereon.

FULL NAME OF SOLE OR FIRST INVENTOR	INVENTOR'S SIGNATURE	DATE
Raymond P. Smith, Jr.		
RESIDENCE		CITIZENSHIP
2521 Linn Street, Williamsport, Pennsylvania 17701		U.S.A.
POST OFFICE ADDRESS		
P.O. Box 294, 129 Susquehanna Street, Williamsport, Pennsylvania 17701		
FULL NAME OF SECOND JOINT INVENTOR, IF ANY	INVENTOR'S SIGNATURE	DATE
RESIDENCE		CITIZENSHIP
POST OFFICE ADDRESS		
FULL NAME OF THIRD JOINT INVENTOR, IF ANY	INVENTOR'S SIGNATURE	DATE
RESIDENCE		CITIZENSHIP
POST OFFICE ADDRESS		

FORM PTO-1597 (10-77) Patent & TM Office - U.S. COMM-D.C.

Reproduced from best available copy.

Attachment B

EPA-AA-TEB-81-13

Evaluation of Gastell
A Device to Modify Driving Habits

February 1981

by

Edward Anthony Barth

Test and Evaluation Branch
Emission Control Technology Division
Office of Mobile Source Air Pollution Control
Environmental Protection Agency

Background

The Environmental Protection Agency receives information about many systems which appear to offer potential for emission reduction and/or fuel economy improvement compared to conventional engines and vehicles. EPA's Emission Control Technology Division is interested in evaluating all such systems because of the obvious benefits to the Nation from the identification of systems that can reduce emissions, improve fuel economy, or both. EPA invites developers of such systems to provide complete technical information on the system's principle of operation, together with available test data on the system. In those cases for which review by EPA technical staff suggests that the data available shows promise, confirmatory tests are run at the EPA Motor Vehicle Emission Laboratory at Ann Arbor, Michigan. The results of all such test projects are set forth in a series of Test and Evaluation Reports, of which this report is one.

EPA received an application from Automotive Devices Inc. (ADI) to perform an evaluation of the Gastell Device. Section 511 of the Motor Vehicle Information and Cost Savings Act (15 USC 2011) requires EPA to evaluate fuel economy retrofit devices with regard to both emissions and fuel economy, and to publish the results in the Federal Register. Such an evaluation is based upon valid test data submitted by the manufacturer and, if required, EPA testing.

Gastell is a device that senses vehicle manifold vacuum. The device is preset to give audible and visual signals to the driver so that the driver can efficiently modify his driving habits. Data submitted by ADI showed fuel economy benefits for some drivers and some vehicles. Because of these apparent benefits, EPA decided to conduct confirmatory tests as part of the evaluation. This test program was conducted over an extended time period and consisted of three distinct test phases. This report details the results of this three phase confirmatory test program.

The conclusions drawn from the EPA evaluation tests are necessarily of limited applicability. A complete evaluation of the effectiveness of a concept in achieving performance improvements on the many different types of vehicles that are in actual use requires a much larger sample of test vehicles than is economically feasible in the evaluation test projects conducted by EPA. The conclusions from the EPA evaluation test can be considered to be quantitatively valid only for the specific test cars used; however, it is reasonable to extrapolate the results from the EPA test to other types of vehicles in a directional manner, i.e., to suggest that similar results are likely to be achieved on other types of vehicles.

Summary of Findings (test vehicles grouped together)

The Phase I testing consisted of FTP and HFET dynamometer tests of the Gastell Device. Overall, the use of the Gastell Device as a driving aid did not show a significant effect on the vehicles' fuel economy or emissions for either the FTP or HFET.

The Phase II testing consisted of modified LA-4's (FTP) and acceleration rate studies conducted on the vehicle chassis dynamometer without using the Gastell Device.

The more aggressive (greater acceleration rates) modifications of the LA-4 cycle developed showed little or no change in fuel economy when compared to the standard FTP (LA-4). Therefore, since the preceding tests with the Gastell Device did not show an improvement in the vehicles' fuel economy for either the FTP or HFET, the Gastell Device was not tested with these more aggressive driving cycles.

Evaluation of five vehicles on a test cycle consisting predominately of accelerations did show that there was an average 14.6% improvement in fuel economy between a very low acceleration rate (1 mph/sec.) and the highest acceleration rates used (up to 5 mph/sec.). There was an average 8.5% improvement in fuel economy between the moderate (2 mph/sec) and highest acceleration rates. This indicates that reduced vehicle acceleration rates can improve fuel economy for some vehicle operating conditions. However, when these acceleration fuel economy improvements are adjusted for the average portion of driving time actually devoted to acceleration, the maximum fuel economy savings would be 1.9%; but, in consideration of the constraints of actual driving conditions, a more realistic potential saving would be less than 1/2%. A similar analysis based on fuel consumed during acceleration modes yielded an average estimated improvement potential of 1.3%.

Having found no appreciable fuel economy effects in Phases I and II using the vehicle dynamometer, a road test program, Phase III, was undertaken with the Gastell Device. For the six combinations of vehicle and operator, in only one case did the use of the Gastell Device cause an improvement in vehicle fuel economy greater than 1%. The amount of the fuel economy improvement for this one case was 5%. It is interesting to note that even for this one case, the other less aggressive driver's fuel economy in this vehicle was the same with or without the device and 4% better than the driver who showed an improvement.

In general, the EPA testing of the Gastell Device did not show a positive benefit from its use. None of the Phase I chassis dynamometer tests with the device installed showed a positive fuel economy effect. Four vehicles of varying size and power-to-weight ratio were road tested in San Antonio (with from one to two drivers each) and only one vehicle/driver combination showed a fuel economy improvement (5%). It is concluded from the test data available that only drivers with aggressive driving behavior (or other driving habits that involve excessive throttle manipulation) could benefit from use of this device and then only if: (1) their vehicle happened to have the fuel economy response characteristics that favorably matched the activation setting of the device and (2) the driver consistently responded to the device signal and refrained from such aggressive driving.

Description of Device

Gastell is an add-on device developed and marketed by Automotive Devices, Inc. of Williamsport, Pennsylvania. The device senses vehicle manifold vacuum and emits an audible and visual signal when the manifold vacuum drops below a preset level. The driver responds by easing off the accelerator, thereby achieving a higher manifold vacuum which turns these signals off. The vehicle is thus operated at a higher manifold vacuum

level which the manufacturer claims is more fuel efficient.

The manufacturer claims the following benefits for Gastell:

1. Fuel economy savings of up to 30%, depending on driving habits.

2. Indicates engine problems when the alarm and light are on more frequently than usual (i.e., functions as a vacuum gauge).

The unit is packaged in a 4 inch by 3 inch by 2 inch case that mounts to the vehicle dash panel. A picture of the unit and operating instructions are contained in the "Gastell Operator's Manual" in Appendix A.

The unit is easily installed. A vacuum line is attached to a source of manifold vacuum and the electrical connections are attached to the vehicle's 12 volt power. A copy of the manufacturer's installation instructions is given in Appendix A.

Test Vehicle Description

Phase I: FTP and HFET chassis dynamometer testing with the Gastell Device used the following three test vehicles:

A 1979 Buick Regal equipped with a 3.8 liter V-6 engine and an automatic transmission. This vehicle used EGR and an oxidation catalyst for emission control.

A 1979 Chevrolet Impala equipped with a 5.7 liter V-8 engine and an automatic transmission. This vehicle also used EGR and an oxidation catalyst for emission control.

A 1975 Dodge Dart equipped with a 225 cubic inch inline 6-cylinder engine and an automatic transmission. This vehicle was calibrated to meet the 1975 California emission standards. This vehicle used an air pump, EGR, and an oxidation catalyst for emission control.

A complete description of these vehicles is given in the test vehicle descriptions in Appendix A.

Phase II: Modified LA-4, modified FTP, and acceleration rate chassis dynamometer testing without the device:

A 1980 Chevrolet Citation and a 1975 Chevrolet Nova were used in the development of the more aggressive driving cycles. A more detailed description of these vehicles is given in Appendix B, "Development of a More Aggressive Driving Cycle."

A 1980 Chevrolet Citation, 1980 Dodge Aspen, 1979 Ford Pinto, 1979 Mercury Zephyr and a 1979 Oldsmobile Cutlass were used in the Acceleration Test Program. A more detailed description of these vehicles is given in Appendix C, "Fuel Economy vs. Acceleration Rate."

Phase III: Road testing with the Gastell Device:

A 1980 Chevrolet Citation, 1975 Chevrolet Nova, a 1980 Mercury Cougar XR-7, and a 1979 Mercury Marquis were used in the San Antonio road test program. A more detailed description of these vehicles is given in Appendix D, "Road Testing with the Gastell Device."

Test Procedures

Phase I: FTP and HFET dynamometer testing with the Gastell Device:

Exhaust emission tests were conducted according to the 1977 Federal Test Procedure (FTP) described in the Federal Register of June 28, 1977, and the EPA Highway Fuel Economy Test (HFET), described in the Federal Register of September 10, 1976. The vehicles were not tested for evaporative emissions. Additional tests were conducted as an evaluation tool. These tests consisted of hot start LA-4 cycles. This driving cycle is the basic cycle used in the FTP and the results of these tests are similar to bags 2 and 3 of the FTP.

Prior to initial testing, each vehicle was given a specification check and inspection. The ignition timing, idle speed, and fast idle speed were checked for agreement with the manufacturer's specifications given on the Vehicle Emission Control Information label affixed to the engine compartment. Each vehicle met its manufacturer's specifications and, therefore, no adjustments were required.

The vehicles were inspected for engine vacuum leaks, proper connection of vacuum hoses, functioning PCV valve, oil and water levels, and general condition of the engine compartment. Each test vehicle was in satisfactory condition.

The test program consisted of baseline tests and Gastell tests. The Gastell tests consisted of a standard test procedure (FTP or HFET) which was altered by having the operator back off the accelerator, as necessary, to silence the audible and visual Gastell vacuum alarms. At each test condition a minimum of two FTP and two HFET tests were conducted.

A second Gastell procedure, "modified" was also used. For this procedure the FTP (LA-4) driving cycle was modified by reducing the vehicle acceleration rate to a level just below that at which the device would signal. This smoothed the cycle and would be representative of a very experienced driver's use of the device.

A third Gastell procedure, "frozen accelerator" was also used. For this procedure the operator again backed off the accelerator to shut off the Gastell alarms. The operator then held his foot fixed in this position until the vehicle's speed matched the driving cycle.

Phase II: Modified LA-4, modified FTP, and acceleration rate chassis dynamometer testing without the Gastell Device:

After the conclusion of the Phase I Gastell test program, two additional dynamometer test programs were conducted to further evaluate the effect of acceleration rate on vehicle fuel economy. These test programs and a detailed description of the test procedures are contained in Appendices B and C of this report.

"Development of a More Aggressive Driving Cycle," Appendix B, was a short test program in which the basic FTP driving cycle, the LA-4 was modified. The LA-4 cycle was modified by increasing the acceleration rates at speeds below 25 mph. Two cycles were used - Mod. 1 which used slightly increased acceleration rates and Mod. 2 which used nearly wide-open-throttle (WOT) accelerations.

"Fuel Economy vs. Acceleration Rate," Appendix C, was a short test program which used a test cycle consisting of a series of accelerations. The vehicle was accelerated at a fixed rate to a cruise speed, cruised for a few seconds, and then decelerated at a fixed rate of 2 mph/sec. The cruise time was chosen so that all tests to a selected cruise speed would be of equal distance. This sequence was repeated 4 times (5 total cycles). This test sequence was done for each combination of acceleration rate and final cruise speed.

The complete test matrix used was:

	Acceleration Rate mph/sec				
Vehicle Speed change mph	1.0	2.0	3.3	4.0	5.0
0-35	x	x	x	x	x
0-45	x	x	x		
20-35	x	x	x	x	x
30-45	x	x	x		

The dynamometer rolls were coupled to minimize tire slippage. Fuel consumption was measured with a fuel flowmeter. No gaseous emission data was taken.

Phase III: Road Testing with the Gastell Device procedures:

"Road Testing with the Gastell Device," Appendix D, was a carefully controlled road test with the Gastell Device. The drivers drove the vehicles over a specified road route in San Antonio. Testing was done both with and without (baseline) the Gastell Device. Details of the test program and the San Antonio test route are given in Appendix D.

Discussion of Results

The FTP and HFET test results are summarized in Tables I and II below. The test results of individual tests are given in Tables A-I, A-II, and

A-III in Appendix A. Results of the tests using the more aggressive driving cycle are given in Table B-1 Appendix B. Results of the acceleration rate tests are given in Tables C-II thru C-V of Appendix C. Results of the road tests are given in Table III.

1. Federal Test Procedure Results - Phase I dynamometer testing with Gastell

The test results are summarized in Table I below:

Table I
Average Vehicle FTP Emissions
grams per mile

Test Condition	HC	CO	CO_2	NOx	MPG
Buick Regal-FTP					
Baseline Avg. (2 tests)	.72	7.89	459	1.24	18.8
Gastell Avg. (2 tests)	1.07	7.71	464	1.01	18.5
Chevrolet Impala-FTP					
Baseline Avg. (3 tests)	.63	4.80	565	1.27	15.5
Gastell Avg. (2 tests)	.56	4.72	563	1.34	15.5
Dodge Dart-FTP					
Baseline Avg. (2 tests)	.44	6.53	550	2.05	15.8
Gastell Avg. (2 tests)	.38	5.86	555	1.83	15.7
Gastell Frozen Accelerator Avg. (2 tests)	.53	6.76	569	1.82	15.3

Overall the Gastell Device did not show a significant positive or negative effect on vehicle FTP emissions or fuel economy.

The use of the Gastell Device as a driver's aid did not significantly affect the vehicle's HC emissions.

The vehicle's CO emissions were also not significantly affected by the use of the Gastell Device.

Gastell caused mixed effects on NOx emissions. The Buick's and Dart's FTP NOx emissions were significantly lowered. The Impala's NOx emissions were judged to be unchanged.

The amount the Gastell Device required the driving cycle to be modified varied appreciably between vehicles. The Gastell Device typically sounded 15 to 20 times during the standard FTP cycle for the Buick. However, the easing off of the accelerator only caused the driving cycle to be appreciably altered during the long hard acceleration occurring at 195 seconds in bags 1 and 3 of the FTP for the Buick. For the Impala, the device rarely sounded, and the device only caused the driving cycle to be appreciably modified at 195 seconds in bag 1 of the FTP. For the Dart, the device sounded 20 times during the FTP and appreciably altered the driving cycle most of the time.

2. Highway Fuel Economy Test Results - Phase I dynamometer testing with Gastell

The test results are summarized in Table II below:

Table II
Average Vehicle HFET Emissions
grams per mile

Test Condition	HC	CO	CO_2	NOx	MPG
Buick Regal-HFET					
Baseline Avg. (2 tests)	.07	.39	348	1.30	25.4
Gastell Avg. (2 tests)	.07	.48	351	1.44	25.2
Chevrolet Impala-HFET					
Baseline Avg. (4 tests)	.11	.59	410	1.51	21.6
Gastell Avg. (2 tests)	.09	.07	404	1.56	22.0
Dodge Dart-HFET					
Baseline Avg. (2 tests)	.05	.21	359	3.13	24.7
Gastell Avg. (2 tests)	.05	.16	359	2.20	24.7
Gastell Frozen Accelerator Avg. (2 tests)	.08	.12	363	2.84	24.7

Overall the use of the Gastell Device as a driver's aid did not show a significant positive or negative effect on vehicle HFET emissions or fuel economy.

The Gastell device did not significantly affect the vehicle's HC emissions. The HC emissions were at relatively low levels both with and without the usage of the device.

Although one vehicle's CO decreased, overall the average emissions were not significantly affected by the use of the Gastell Device. However, these changes were not significant. The change in the Impala's CO emissions was judged to be not caused by the use of Gastell.

Overall, the vehicle's NOx emissions were unaffected by using Gastell.

The amount the Gastell Device required the driving cycle to be modified varied appreciably between vehicles. The device typically signalled during the initial long acceleration and the acceleration midway through the cycle. The Buick's, Impala's and Dart's highway driving cycle were only slightly modified at these points.

3. Alternative Driving Cycles Results - Phase I dynamometer testing with Gastell

Because in the initial EPA tests Gastell had, in general, shown no effects on emissions or fuel economy, alternative tests were conducted in an effort to confirm the manufacturer's claimed benefits. Since the

continual modulation of the throttle in response to the device could potentially adversely affect vehicle emissions and/or fuel economy, two alternative cycles were tried. These were the "modified" and "frozen accelerator" cycles.

The "modified" driving cycle was an FTP (LA-4) cycle in which the vehicle acceleration rate was reduced to a level just below the level at which the device would signal. This smoothed the cycle and would be representative of a very experienced driver's use of the device. A "modified" LA-4 cycle was conducted using the Buick Regal (see Table A-III). These "modified" LA-4 tests showed no improvement in emissions or fuel economy over the Gastell LA-4 tests.

The "frozen accelerator" cycle was an FTP or HFET in which the driver backed off the accelerator sufficiently to silence the Gastell Device. The driver then held the accelerator frozen at that setting until the vehicle speed matched the driving trace. Frozen accelerator tests were done for the FTP and HFET for the Dart. These tests (see Tables I and II) showed no significant improvement in emissions or fuel economy for either the FTP or HFET.

4. Post Test Gastell Checkout - Phase I

The Gastell units tested were provided by the manufacturer and therefore presumed to function properly. However, since no benefits were perceived in the test results, the units were checked at the conclusion of testing. The vacuum specifications for the devices and the results of these checks were:

Gastell Vacuum Checks
Inches Hg

	Gastell 6 Cyl. Vehicle Unit		Gastell 8 Cyl. Vehicle Unit	
	On	Off	On	Off
Mfg. Spec.	5	6	7	8
Test Unit 1	5.3	5.7	6.7	7.3
Test Unit 2	5.1	5.9	-	-

Therefore, all units were found to function properly.

5. Post Test Vehicle Inspection - Phase I

All vehicles were inspected at the conclusion of testing. The Impala and Dart were acceptable. However, the Buick Regal had a noticeable vacuum leak at the throttle shaft. The shaft had considerable lateral play. When the shaft was sprayed with a carburetor cleaner, the engine idle speed noticeably increased.

Since the effect of the leak would be lowered manifold vacuum, the leak would tend to trigger the Gastell device sooner. Therefore, on a Buick

without the leak, Gastell would trigger less often and have an expected lesser effect. Thus, since there was a negligible Gastell effect on the test vehicle's emissions or fuel economy, it is reasonable to assume that the Gastell would show a lesser benefit on another similar vehicle. Therefore, the Buick data is included in this report.

6. Development of a More Aggressive Driving Cycle - Phase II modified LA-4 and modified FTP dynamometer testing without Gastell

The original test program for the Gastell Device was based on the use of the FTP and HFET cycles and the results showed no significant negative or positive effect on either emissions or fuel economy. Since an acceleration limiting device was expected to reduce fuel consumption, additional testing to investigate the effects of acceleration was undertaken.

Two altered LA-4 cycles were devised with greater acceleration rates at the lower vehicle speeds. A small test sequence was run to evaluate the suitability of these cycles for testing the Gastell Device. For this study several available EPA test vehicles underwent a variety of emission tests with modified cycles and emission tests using dynamometer coupled rolls. Results of these tests are given in Table B-I of Appendix B. The results are also summarized in Appendix B.

An analysis of the data from these tests indicated that the fuel economy with the more aggressive cycles was not measurably different from that on the standard FTP. Since the Gastell device had made no measurable fuel economy difference on the FTP, it was concluded that the same result would be found with the revised cycles and no tests were run with the device installed.

7. Fuel Economy vs. Acceleration Rate Tests - Phase II dynamometer acceleration testing without Gastell

Since the net result of the preceding studies was that, for the cycles used, there was no effect on fuel economy, a test cycle consisting predominantly of accelerations was developed to directly quantify the effect of fuel economy versus acceleration rate. For this study five available EPA test vehicles were used. Results of these tests are given in Tables C-II thru C-V of Appendix C and these results are plotted in Figures C-1 thru C-5 of Appendix C.

Vehicle manifold vacuum was measured during these acceleration tests. Based on the vacuum levels at which the Gastell device would function for 4, 6, and 8 cylinder engines - all five of these vehicles would have given signals at very low acceleration rates. The Citation would have signaled at acceleration rates slightly less than 2 mph/sec. The Aspen, Cougar, Zephyr, Pinto and Cutlass at rates near 1 mph/sec.

For this acceleration study, the average improvement in vehicle fuel economy between worst case (greatest acceleration rate) and the lowest acceleration rate (1 mph/sec.) was 14.6%. The improvements ranged from 6.0 to 28.9% (see Table C-III). The average improvement in vehicle fuel economy between worst case and 2 mph/sec. was 8.5%. This improvement ranged from 1.9% to 15.5% (see Table C-IV).

The above effects - no discernable improvement in transient (i.e. FTP) fuel economy even though the preceding acceleration study shows differences in fuel economy - is explained by considering available data on vehicle operating characteristics(1). In these chase car studies, it was found that less than 13% of vehicle operating time is spent accelerating and only 34% of these accelerations occur at rates above 2.2 mph/sec. Even if the 14% improvement in fuel economy was applied to all the 13% of vehicle operation involving acceleration, the maximum possible fuel savings would be 1.9%. To achieve these savings would require that the driver always reduced acceleration to a level on the order of one mph/sec. when signalled by the device. More realistically the fuel economy improvement should only be applied to the accelerations above 2.2 mph/sec. since accelerations at rates as low as one mph/sec. would many times be unsafe. Combining the potential fuel economy improvement (8.5%), the percentage of time accelerating (13%) and the percentage of time at accelerations above 2.2 mph/sec. (34%), gives an overall anticipated improvement of .4%. Such a fuel economy increment is below the threshold of sensitivity for all but the most highly controlled tests.

A similar analysis can be applied to the fuel consumption data from the GM study. It was found in that study that 20.8% of total fuel used per trip is consumed during acceleration modes. Again, if the Gastell Device would reduce all acceleration rates down to the order of one mph/sec., the maximum potential savings would be 14.6% of 20.8% which is equal to 3%. If the Gastell device alerts the driver to only those accelerations above two mph/sec., then only the fuel consumption during accelerations at rates above two mph/sec. would be reduced. This yields a potential savings of 14.6% of (37.5% of 20.8%) equals 1.3%. Validation of this potential improvement would also require a large number of controlled tests.

8. Road Tests with the Gastell Device - Phase III

During the course of the various phases of the chassis dynamometer test program, the developer of the device, Mr. Ray Smith, was kept abreast of the results. As more and more of the testing continued to yield negative results, he became critical of the chassis dynamometer procedure and made a number of suggestions, primarily directed toward road testing of the device. In an effort to try every reasonable possibility in evaluating the device, his suggestion was pursued.

EPA first looked into the feasibility of a road test program in some type of fleet operation. The basic approach was for the selection of government owned vehicles which are operated by the same driver over essentially the same route every day. After investigating several options, the particular fleet considered was that of the United States Park Police which operates in the metropolitan Washington DC area. The Park Police

---

(1) "Measurement of Motor Vehicle Operation Pertinent to Fuel Economy" (GM Chase Car Study), SAE Paper 750003, February, 1975

volunteered the availability of 20 of their vehicles, 10 of which could be used as test cars and 10 for control. After an appropriate interval, the control and test fleets could be reversed. It was recognized that the vehicle operation would not be representative of private owner usage and most importantly, that test variability involving fleet tests is generally very high. Estimates of the average effectiveness of the device documented in Section 7 above indicated that a more controlled road test might be necessary so the Park Police fleet test was deferred.

A pilot test program was run over a route in Ann Arbor which had previously been selected for durability testing. The route, which had been approved for the EPA durability driving schedule, is approximately 30 miles long with an average speed of 34 miles per hour. An available EPA test vehicle (a 1980 Citation - see vehicle description in Appendix D) was instrumented with a Fluidyne fuel flow meter and driven repeatedly over the route. Fuel flow was totaled over each circuit of the 29.5 mile route and the data with and without the device is plotted in Figure 1. Data variability was high and at least part of the variability was attributed to the late autumn weather conditions with frequent rain, variable winds, and wide temperature excursions. Because of this variability, it was decided that a road test program should be conducted in the southwestern United States where more temperate weather conditions are available.

San Antonio, Texas was selected as the test site for two major reasons. An urban road route had been defined there several years ago for use in an emission factors program which has traffic conditions known to be representative of most cities. Southwest Research Institute is also there and offered the use of their laboratory facilities for any work which needed to be done on test cars. Two EPA technicians drove the instrumented Citation to San Antonio and rented a late model full-sized car with a V-8 engine (1980 Cougar - see vehicle description in Appendix D) as a second test car. Each driver took turns driving the two cars with and without the Gastell Device installed over the San Antonio road route. Sufficient driving was done prior to the test to familiarize the drivers with the route and with the test vehicles. The Ann Arbor experience had suggested that such familiarization would enhance repeatability during a test. Further information on the driving route and the test procedures used are given in Appendix D.

Results of the tests are shown in Figures 2 through 5. These figures illustrate that only one of the four vehicle/driver combinations showed a significant positive result with the devices. One driver had better fuel economy on both cars without the driver's aid than the other driver had on either car with the driver's aid. The data suggest two things. One, that the effectiveness of the device is highly dependent on the driving technique or "agressiveness" of the driver and two, that effectiveness is also a function of characteristics associated with the vehicle.

At the conclusion of this test series the drivers returned to Ann Arbor and the data were analyzed. Table III provides the results of that analysis. Since the device had shown a positive effect on the Cougar and Mr. Smith had suggested that more effectiveness should be found on large cars than small cars like the Citation, a second road test program was

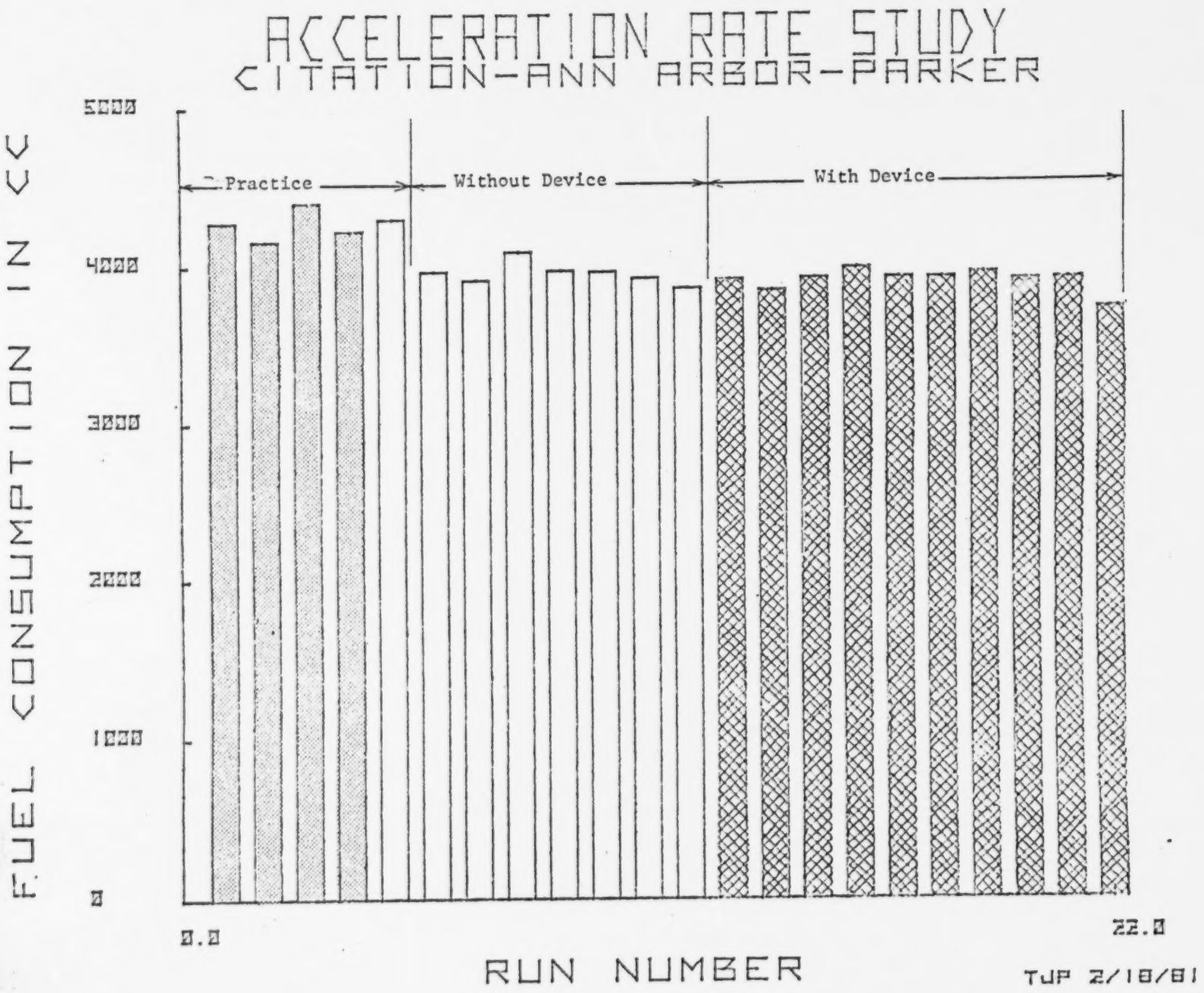

ACCELERATION RATE STUDY
CITATION-ANN ARBOR-PARKER
FUEL CONSUMPTION IN CC
5000
4000
3000
2000
1000
0
Practice
Without Device
With Device
0.0
22.0
RUN NUMBER
TJP 2/18/81

Figure #1

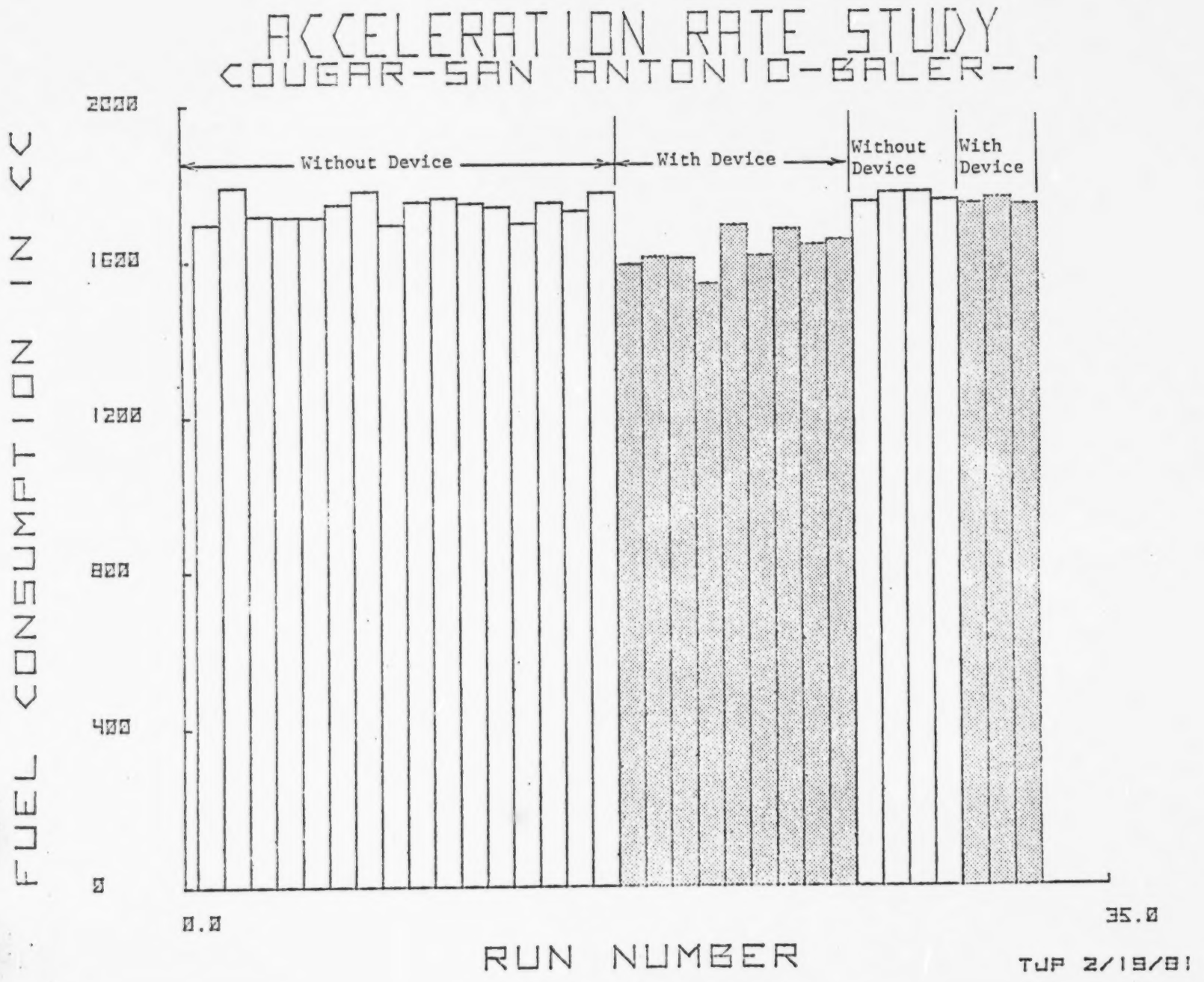

ACCELERATION RATE STUDY
COUGAR-SAN ANTONIO-BALER-1
FUEL CONSUMPTION IN CC
2000
1600
1200
800
400
0
Without Device
With Device
Without Device
With Device
0.0
35.0
RUN NUMBER
TJP 2/19/81

Figure #2

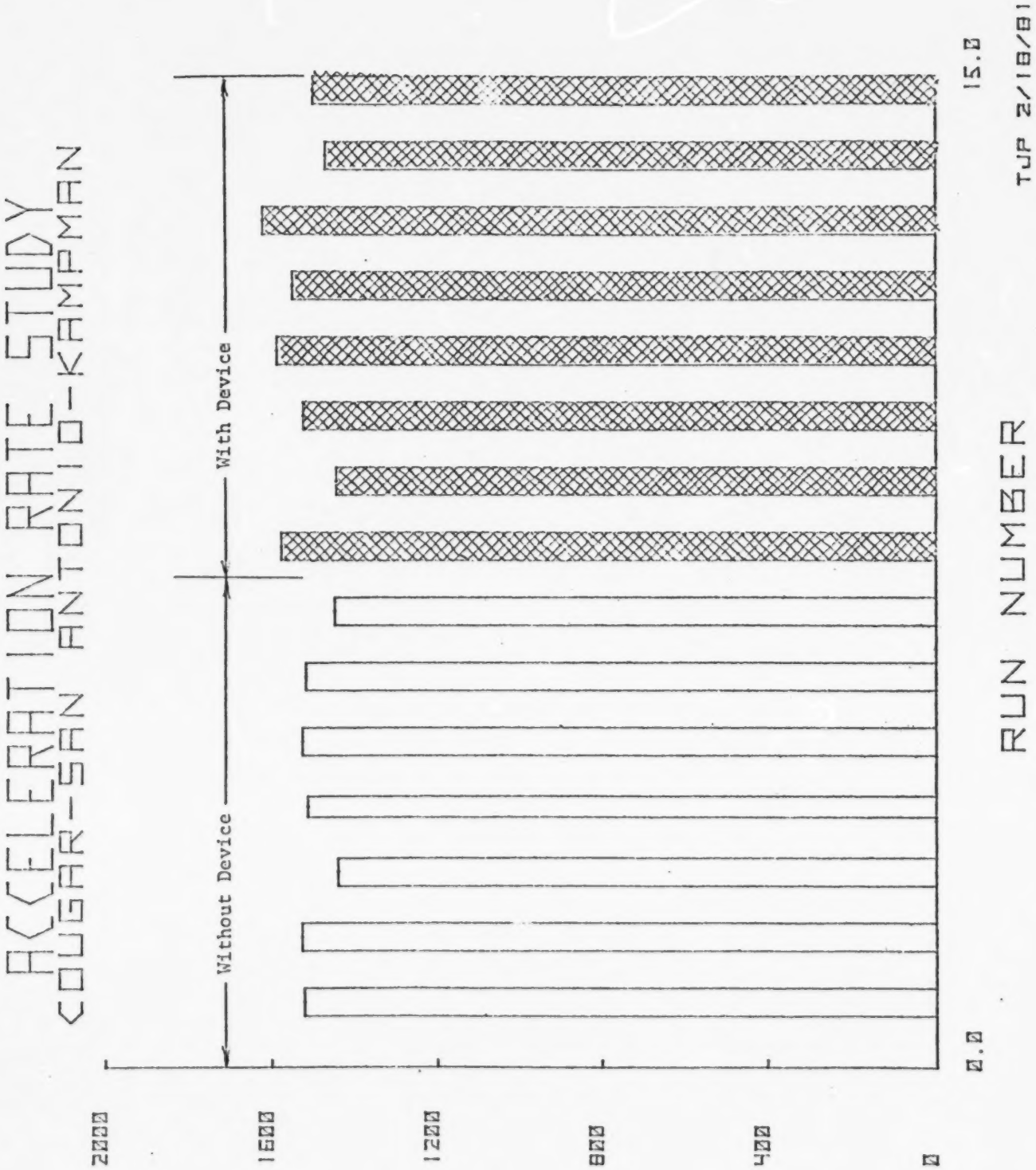

ACCELERATION RATE STUDY
COUGAR-SAN ANTONIO-KAMPMAN
TJP 2/18/81
FUEL CONSUMPTION IN CC
2000
1600
1200
800
400
0
0.0
15.0
RUN NUMBER
With Device
Without Device

Figure #3

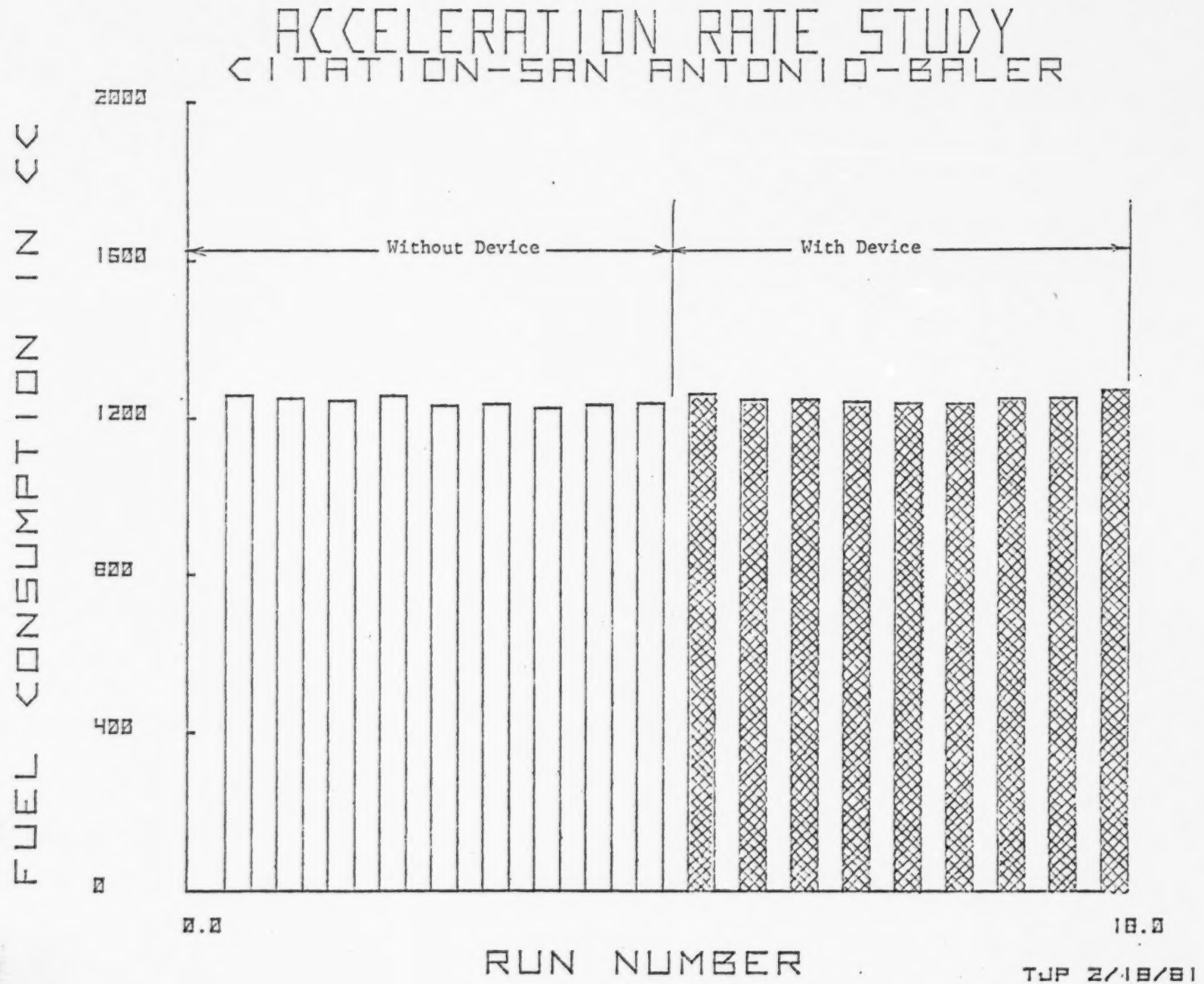

ACCELERATION RATE STUDY
CITATION-SAN ANTONIO-BALER
FUEL CONSUMPTION IN CC
2000
1500
1200
800
400
0
Without Device
With Device
0.0
18.0
RUN NUMBER
TJP 2/18/81

Figure #4

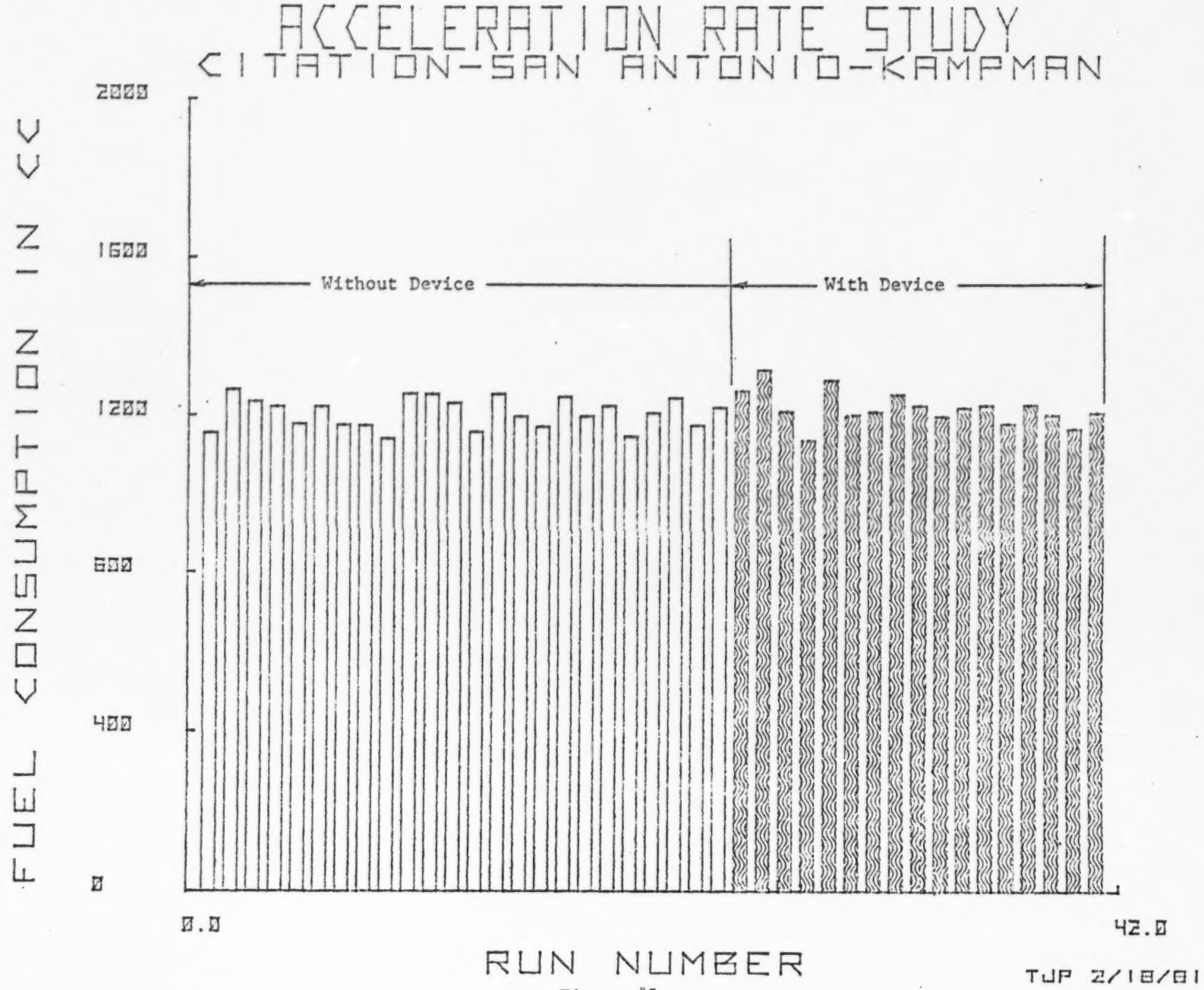

ACCELERATION RATE STUDY
CITATION-SAN ANTONIO-KAMPMAN
FUEL CONSUMPTION IN CC
2000
1600
1200
800
400
0
Without Device
With Device
0.0
42.0
RUN NUMBER
TJP 2/18/81

Figure #5

initiated. Carl Baler, the more aggressive driver, took another EPA test car, a 1975 Nova (see vehicle description in Appendix D) with a 350 engine, to San Antonio and ran the same test sequences run on the previous cars. The baseline was run with no problem and good repeatability, but with the Gastell Device installed it was found that the device never actuated under normal traffic conditions. After making several checks to make sure the device was properly calibrated and that the manifold vacuum tap was correctly installed, it was decided that a test would be run with the calibration changed to actuate on at 9" Hg, off at 10" Hg instead of on at 7" Hg, off at 8" Hg as specified by the manufacturer. This is a two inch change from the normal Gastell V-8 calibration. The tests were resumed and it was found that again the device did not actuate on the test route. Further adjustment was made until the device would actuate on a number of accelerations but the acceleration rates were so limited at these settings (on at 12.5" Hg, off at 13.5" Hg or on at 11.5" Hg, off at 12.5" Hg) that the vehicle could not be driven onto the freeway safely. No setting was found that seemed satisfactory on this high power to weight car.

Furthermore, these tests on the Nova demonstrated that the Gastell Device's calibration needs to be very carefully matched to the specific vehicle. At the manufacturer's calibration setting, the Gastell never signaled. At the calibration settings at which the Gastell signaled, the vehicles fuel economy was altered. The results of both tests were significant, however, at one setting there was a 2.49% fuel economy penalty while the other showed a .96% fuel economy improvement.

The Cougar driven in the earlier test program was rerun to confirm the data previously collected. The results of this retesting showed good agreement with the previous improvement in fuel economy. The results are given in Figure 6.

Another car was sought that would be more representative of high production power-to-weight ratio vehicles. A 1979 Mercury with a 351 CID engine (see vehicle description in Appendix D) was obtained. This has approximately the same power-to-weight as the other high production Ford and General Motors full sized cars. Figure 7 presents the data on the Mercury. The average improvement of .86% was statistically significant.

Tables III and IV present the statistical analysis of all of the road test data. A total of two hundred and thirty road tests were conducted using these vehicles. At the 90% confidence level ($\alpha = .1$) two vehicle/driver combinations showed statistically significant fuel economy improvements. However, at the 80% confidence level ($\alpha = .2$) 4 vehicle/driver combinations showed statistically significant fuel economy changes. Two showed a statistically significant fuel economy improvement and two showed statistically significant fuel economy penalties with the use of the Gastell Device.

Conclusion

In general, the EPA testing of the Gastell Device did not show a positive benefit from its use. None of the Phase 1 chassis dynamometer tests with the device installed showed a positive fuel economy effect. Four vehicles of varying size and power-to-weight ratio were road tested in

San Antonio (with from one to two drivers each) and only one vehicle/driver combination showed an appreciable fuel economy improvement (5%) with the Gastell Device. It is concluded from the test data available that only drivers with aggressive driving behavior (or other driving habits that involve excessive throttle manipulation) could benefit from use of this device and then only if (1) their vehicle happened to have the fuel economy response characteristics that favorably matched the activation setting of the device and (2) the driver consistently responded to the device signal and refrained from such aggressive driving.

None of the Phase I chassis dynamometer tests with the device installed showed a positive or negative effect on emissions.

Intuitively, many people might expect the principles behind the Gastell device to produce an improvement in fuel economy. In fact, at the beginning of the program, EPA evaluation engineers involved in the evaluation expected the device to produce significant benefits and were surprised when the early data showed no effect on fuel economy. This evaluation has been more extensive than most such projects at EPA, but as a result, we are comfortable in supporting this evaluation.

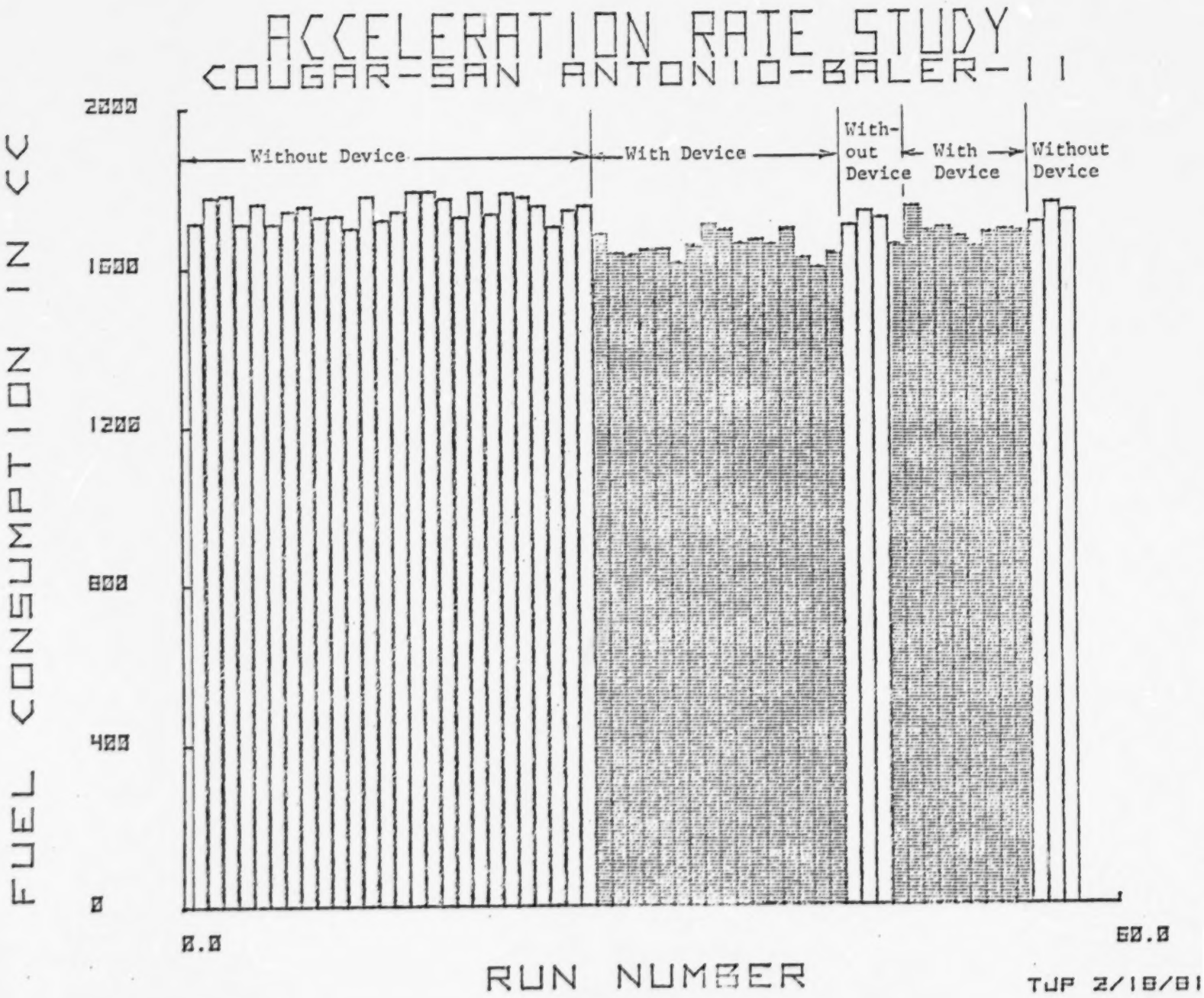

ACCELERATION RATE STUDY
COUGAR-SAN ANTONIO-BALER-11
FUEL CONSUMPTION IN CC
2000
1600
1200
800
400
0
Without Device
With Device
With-out Device
With Device
Without Device
0.0
60.0
RUN NUMBER
TJP 2/18/81

Figure #6

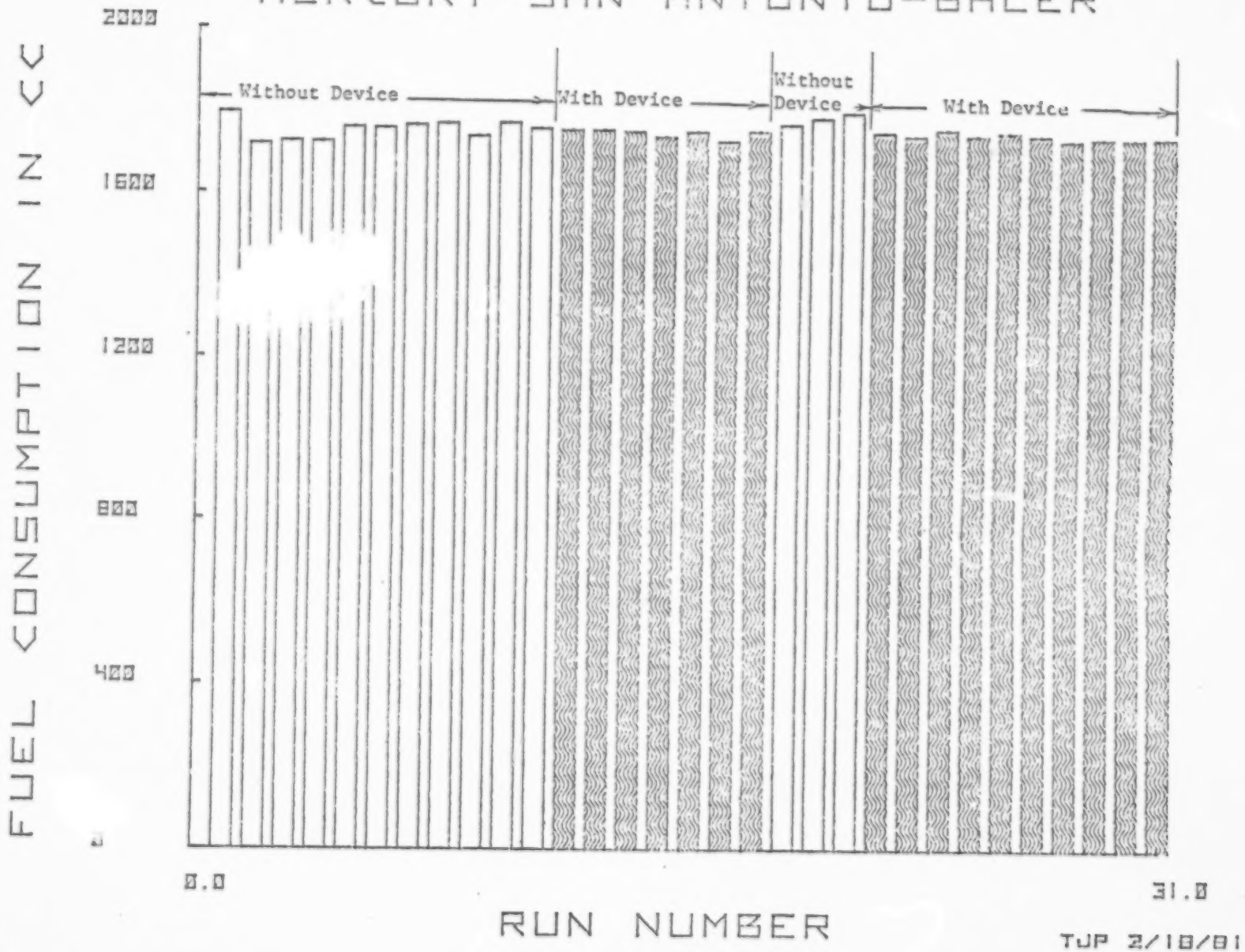

ACCELERATION RATE STUDY
MERCURY-SAN ANTONIO-BALER
FUEL CONSUMPTION IN CC
2000
1600
1200
800
400
0
Without Device
With Device
Without Device
With Device
0.0
31.0
RUN NUMBER
TJP 2/18/81

Figure #7

Table III
Results of San Antonio Road Route Testing

1. Vehicle	Cougar				Citation				Cougar		Mercury Marquis	
2. Driver	Baler		Kampman		Baler		Kampman		Baler (2nd time)		Baler	
3. With or without device	w/o	with	w/o	with	w/o	with	w/o	with	w/o	with	w/o	with
4. Number of tests	20	12	7	8	9	9	24	17	32	25	14	17
5. Average fuel consumption (cc)	1742.5	1655.3	1499.7	1534.7	1243.7	1252.2	1207.2	1221.4	1745.9	1663.8	1759.8	1744.7
6. Standard Deviation	29.07	67.85	38.08	60.65	11.08	11.25	37.75	43.16	29.85	33.63	25.28	8.74
7. Variance	845.05	4603.6	1450.4	3678.7	122.81	126.6	1425.06	1862.60	890.84	1131.16	639.21	73.38
8. Difference between with and w/o testing fuel consumption	(+)87.23 cc		(-)35.00 cc		(-)9.0 cc		(-)14.15 cc		(+)82.15 cc		(+)15.07 cc	
9. % difference fuel consumption	(+)5.13%		(-)2.31%		(-).72%		(-)1.17%		(+)4.82%		(+).86%	
10. Ave. number of signals per cycle	29.5		19.6		4.55		6.76		29.2		5.40	
11. Calculated T Statistic	4.23		1.36		1.71		1.09		9.61		2.13	
12. Calculated degrees of Freedom	14.0		14.0		12.0		33		50		16	
13. Tablulated T Statistics for α =.1	1.761		1.761		1.734		1.694		1.675		1.746	
for α =.2	1.345		1.345		1.330		1.308		1.299		1.337	
14. Significant? at α =.1	Yes		No		No		No		Yes		Yes	
at α =.2	Yes		Yes (marginal)		Yes		No		Yes		Yes	

Table IV
Results of San Antonio Road Route Testing on Chevrolet Nova

1. Vehicle	Nova	Nova	Nova	Nova	Nova
2. Driver	Baler	Baler	Baler	Baler	Baler
3. Calibration - On" Hg, Off" Hg	N/A	7"Hg, 8"Hg(1)	9"Hg, 10"Hg	12.5"Hg, 13.5"Hg(2)	11.5"Hg, 12.5"Hg(3)
4. With or without device	without	with	with	with	with
5. Number of tests	16	11	5	4	2
6. Average fuel consumption (cc)	1793.5	1790.7	1782.9	1838.7	1776.3
7. Standard Dev.	28.94	24.99	23.45	29.85	3.50
8. Variance	837.52	624.50	549.90	891.02	12.25
9. Difference between with and w/o testing fuel consumption	-	(+)2.80	(+)10.60	(-)45.20	(+)17.20
10. % difference fuel consumption		(+) .16%	(+) .59%	(-)2.49%	(+) .96%
11. Ave. number of signals per cycle		0.0	0.0	17.4	8.5
12. Calculated T Statistic		.268	.832	2.725	2.203
13. Calculated degrees of Freedom		26	10	6	18

14. Tablulated T Statistics				
for α =.1	1.706	1.812	1.943	1.734
for α =.2	1.315	1.372	1.440	1.330
15. Significant?				
at α =.1	No	No	Yes	Yes
at α =.2	No	No	Yes	Yes

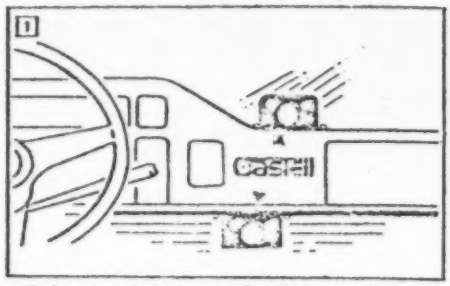
---

(1) Gastell Device manufacturer setting.
(2) When Gastell was recalibrated to this setting, vehicle could not safely be driven on to freeway.
(3) When Gastell was recalibrated to this setting, vehicle acceleration was marginal for entering the freeway.

Gastell™ INSTALLATION INSTRUCTIONS

AUTOMOTIVE DEVICES, INC.

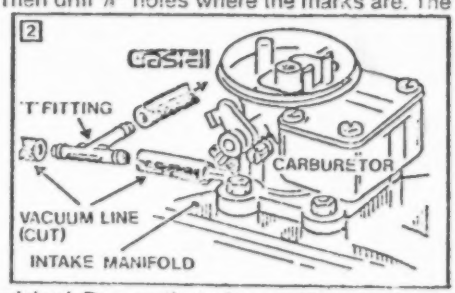
For Models 2004, 2005, 2006, 2008



- Your car or truck should be tuned before installation.
- Read ALL instructions before starting installation. All necessary hardware to install Gastell is included in hardware kit.

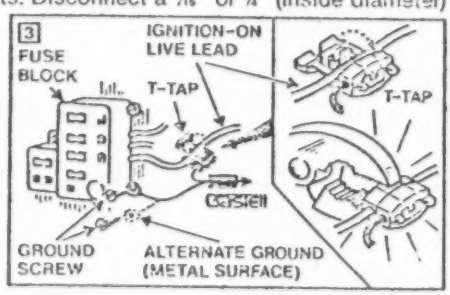
1. Select location for Gastell, preferably centered under dash (fig. 1), but make sure that the chosen location will not interfere with the operation of your vehicle. Attach mounting brackets to Gastell. Note that the brackets are reversible for either under—or above—dash mounting (fig. 4). Use the two hex head sheet metal screws furnished with internal-tooth lock washers. DO NOT OVER TIGHTEN.

2. Most American-made cars have ashtrays held by two sheet metal screws. Often the spacing of these screws is equal to that of the Gastell brackets. So before you drill, try to use the ashtray mounting screws. If you find that you must drill, position Gastell to dash and hold firmly. Use lead pencil to mark hole locations. Then drill ⅛" holes where the marks are. The hex head sheet metal screws furnished will work in plastic or metal. Use them to fasten the Gastell to the dash. Do not over tighten.



3. Choose desired routing for Gastell vacuum hose and electrical wiring. Do not make electrical or hose connection yet. The vacuum hose must go through the firewall without pinching or chaffing. Try to locate an existing hole that has a rubber grommet. On most vehicles, the emergency brake, speedometer, and gas pedal cables pass through a rubber grommet in the firewall. If you can, enlarge this grommet to accept vacuum line. If this cannot be done, drill ½" hole in a nearby location. Install furnished rubber grommet; then insert rubber hose from Gastell through firewall to engine compartment. Do not stretch or pull Gastell hose. The electrical wiring from Gastell may be connected to the fuse panel or ignition switch. The wires should be routed along the path of existing auto wiring. Use wire ties furnished. Be sure that wires and hose are clear of all sharp surfaces and clear of clutch, brake, accelerator, and other moving parts.

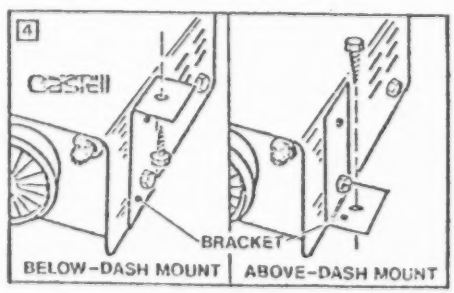
4. Attach Gastell vacuum line to engine intake manifold system. To locate the proper vacuum line on the intake manifold, start engine. Keep hands and loose clothing free of fan blade or moving parts. Disconnect a 5/16" or ¼" (inside diameter) hose from the intake manifold while engine is running (see fig. 2). When the proper vacuum hose is removed, there will be a distinct change in idle speed. Once proper vacuum line is identified, turn off engine, and reconnect vacuum line to manifold. Then cut the vacuum line in an appropriate location, preferably 5" to 6" from a connection; insert "T" fitting furnished. Attach Gastell vacuum line securely to remaining branch of "T" (fig. 2). Be sure Gastell vacuum line is away from all moving parts. Using wire tie furnished, secure vacuum line to existing wiring on hoses.



5. Locate your vehicle's fuse panel and wiring, and identify a source of electricity that has current only when the key is in the "on" position: this may be a wire that runs to any accessory that is activated by turning on the key. To this wire, the red wire from Gastell (with Electro T-Tap splicer) is connected (fig. 3). Use standard pliers for installing T-Tap splicer. Wrap around a wire from 14 to 20 gauge. Apply pliers, and squeeze until T-Tap locks. Connect the remaining black wire with the eyelet to a suitable ground. If existing ground screw is not available, drill ⅛" hole in sheet metal near fuse panel. Use hex head sheet metal screw furnished with internal tooth lock washers. Do not over tighten. Wrap up any extra wire and secure to existing wiring with wire tie furnished. Do not shorten wiring or hoses: your next vehicle may require the extra length.

Now your Gastell is ready to operate. Start engine. When the key is turned on, red light and audible tone will operate. As soon as the engine starts, the light and tone will cease to operate, and the green light will go on. Keep your Gastell operating in the green for maximum mileage.

See operating manual for operation.



- Warning: When drilling holes anywhere in your vehicle, make sure your drill does not come in contact with wiring or hoses. Common sense and caution should be exercised in drilling. Electrical damage could result if you ignore this warning.

COPYRIGHT ©1979

AUTOMOTIVE DEVICES, INC. 129 Susquehanna Street, P.O. Box 3513, Williamsport, PA 17701

Appendix A
Test Vehicle Description

Chassis model year/make-1979 Buick Regal
Vehicle ID 4J47A9H123351

Engine

type	Otto Spark, V-6
bore x stroke	3.8 x 3.4 in.
displacement	3.8 liter/231 CID
compression ratio	8.0:1
maximum power @ rpm	115 hp/86 KW @ 4800 rpm
fuel metering	2 Venturi carburetor
fuel requirement	unleaded, tested with indolene HO unleaded

Drive Train

transmission type	3 speed automatic
final drive ratio	2.40

Chassis

type	2 Dr. Sedan
tire size	P 195/75 R 14
curb weight	3312 lb/1502 kg.
passenger capacity	5

Emission Control System

basic type	EGR Oxidation Catalyst

Vehicle Odometer mileage at start of program	14950 miles

Appendix A (cont.)
Test Vehicle Description
Chassis model year/make-1979 Chevrolet Impala
Vehicle I.D. 1L47L9S115799

Engine

type	Otto Spark, V-8
bore x stroke	4.00 x 3.48 in/101.6 x 88.4 mm
displacement	350 CID/5.7 liter
compression ratio	8.3:1
maximum power @ rpm	170 hp/126 kW
fuel metering	4 venturi carburetor
fuel requirement	Unleaded, tested with indolene HO unleaded

Drive Train

transmission type	3 speed automatic
final drive ratio	2.41

Chassis

type	2 door sedan
tire size	FR 78 x 15
curb weight	3840 lb/1742 kg
inertia weight	4000 lb.
passenger capacity	6

Emission Control System

basic type	EGR Oxidation Catalyst

Vehicle mileage at start of test program . . . . . 12,700 miles

Appendix A (cont.)
Test Vehicle Description

Chassis model year/make-1975 Dodge Dart
Emission Control System-Air Pump, Catalyst, EGR
Vehicle I.D. LH41C5B290359

Engine

type	Inline 6, 4 cycle
bore x stroke	3.40 x 4.125 in.
displacement	225 CID/3687 cc
compression ratio	8.4:1 fuel metering
carburetor	1 Venturi
fuel requirement	unleaded, tested with Indolene HO unleaded

Drive Train

transmission type.	3 speed automatic
final drive ratio.	2.75

Chassis

type	4 door sedan
tire size	D78 x 14
inertia weight	3500 lbs.
passenger capacity	6

Emission Control System

basic type	air pump oxidation catalyst EGR calibrated to 1975 California standards

Vehicle Odometer mileage at start of test.	21,500 miles

Appendix A (cont.)
Table A-I
FTP Mass Emissions
grams per mile

Test Condition	Test No.	HC	CO	CO_2	NOx	MPG
Buick Regal						
baseline	80-0453	.76	8.03	465	1.24	18.5
baseline	80-0567	.68	7.75	453	1.24	19.0
Gastell	80-0455	1.45	8.82	467	.90	18.3
Gastell	80-0569	.69	6.60	461	1.11	18.7
Chevrolet Impala						
Baseline	80-0573	.72	4.85	569	1.29	15.3
Baseline	80-0575	.59	4.54	565	1.29	15.5
Baseline	80-0446	.58	5.01	560	1.23	15.6
Gastell	80-0578	.59	5.59	561	1.43	15.5
Gastell	80-0576	.53	3.84	565	1.24	15.5
Dodge Dart						
Baseline	80-0246	.38	6.06	547	1.99	15.9
Baseline	80-0735	.50	7.00	553	2.11	15.7
Gastell	79-4788	.29	5.20	553	1.85	15.8
Gastell	80-0244	.47	6.51	557	1.81	15.6
Gastell (Frozen)	80-0579	.59	7.61	574	1.73	15.1
Gastell (Accelerator)	80-0581	.47	5.90	563	1.91	15.5

Appendix A (cont.)
Table A-II
Highway Fuel Economy Test Mass Emissions
grams per mile

Test Condition	Test No.	HC	CO	CO_2	NOx	MPG
Buick Regal						
Baseline	80-0454	.06	.32	351	1.29	25.2
Baseline	80-0568	.07	.45	345	1.30	25.6
Gastell	80-0456	.07	.78	354	1.59	24.9
Gastell	80-0570	.06	.18	347	1.29	25.5
Chevrolet Impala						
Baseline	80-0438	.10	.54	402	1.55	2
Baseline	80-0445	.12	.72	410	1.51	2i.6
Baseline	80-0574	.12	.69	415	1.52	21.3
Baseline	80-0886	.11	.08	414	1.55	21.9
Gastell	80-0831	.09	.05	403	1.56	22.0
Gastell	80-0577	.09	.08	404	1.55	21.9
Dodge Dart						
Baseline	80-0316	.03	.19	356	2.78	24.9
Baseline	80-0734	.06	.22	362	3.48	24.5
Gastell	79-4789	.05	.18	358	2.59	24.8
Gastell	80-0245	.05	.13	361	1.81	24.6
Gastell (Frozen)	79-0580	.05	.24	363	2.88	24.4
Gastell (Accelerator)	79-0582	.10	.00	362	2.79	24.4

Table A-III
LA-4 Mass Emissions
grams per mile

Test Condition	Test No.	HC	CO	CO_2	NOx	MPG
Buick Regal						
Baseline	80-0663	.44	1.75	432	.72	20.3
Gastell	80-0661	.19	1.04	433	1.01	20.4
Gastell	80-0662	.21	1.11	434	1.03	20.3
Gastell (modified)	80-0571	.23	1.12	428	.96	20.6
Gastell (modified)	80-0572	.23	1.07	426	.93	20.7
Dodge Dart						
Gastell	79-4790	.64	13.72	572	1.82	14.9

Appendix B
Development of A More Aggressive Driving Cycle

In order to evaluate the effects of more aggressive driving behavior on fuel economy, EPA modified the standard FTP (LA-4) cycle by increasing the acceleration rates at speeds below 25 mph. The Mod. 1 cycle had slightly greater acceleration rates than the LA-4. The Mod. 2 cycle had nearly WOT accelerations. The intention was to use these cycles as a new reference with which to evaluate the effects of driver habit modification prescribed by Gastell.

A small test sequence was undertaken to evaluate the suitability of these cycles for testing Gastell. For this study two available EPA test vehicles were used for emission tests with the standard and modified driving cycles. The results of these tests are tabularized in this Appendix and are summarized below:

1.) For the LA-4 cycle, a slightly greater acceleration rate (Mod #1) did not effect the Citation's HC emissions, NOx emissions or fuel economy. CO emissions increased 58%.

2.) For the LA-4 cycle a greater acceleration rate (Mod #2) the Citation's HC emissions were doubled, CO emissions were increased fivefold, NOx emissions were unchanged, and fuel economy was reduced 1%. The Nova's HC emissions doubled, CO emissions were increased tenfold, NOx emissions increased 11%, and fuel economy was reduced 3%*.

Because it was anticipated that there might be increased tire slippage (see note) at higher acceleration rates, a test sequence was conducted with coupled rolls. The results of these tests were similar to the preceding tests with uncoupled rolls (the standard test condition).

Note: Tire slippage means that the front roll (inertia and power absorbing unit roll) lags the rear roll (vehicle speed roll). This effect would tend to mask the loading effects of increased vehicle acceleration rates.

The overall analysis of this effort to evaluate more aggessive driving behavior was that the mod #1 cycle used appeared to have little or no effect on fuel economy. Since the mod #2 cycle used WOT accelerations for all accelerations and was, therefore, not a representative cycle and the mod #1 cycle showed minimal differences, it did not appear fruitful to try developing a test cycle to test the Gastell Device. Therefore, no Gastell testing was attempted with these cycles.

The test vehicles used for this testing, a 1980 Chevrolet Citation and a 1975 Chevrolet Nova were also used in the road testing and are described in more detail in Appendix D.

*Subsequent to these emission and fuel economy tests with the Nova, the vehicle was discovered to have a carburetor problem. This problem may have contributed in a large part to the emissions and fuel economy results of the mod #2 tests and, therefore, the findings of this vehicle are suspect.

Table B-I
Composite FTP and Hot Start LA-4 Emissions
grams per mile

Test Date	Test Number	Test Type	Accel. Type	Roll Configuration	HC	CO	CO2	NOx	MPG
1980 Citation with P 185/80 R 13 radial tire, 7.3 hp, 2750 lb. inertia weight									
2-7-80	80-1475	Hot LA-4	Mod #1	Standard	.08	.84	370	.34	23.9
2-7-80	80-1476	Hot LA-4	Stand.	Standard	.04	.58	370	.34	23.9
2-7-80	80-1477	Hot LA-4	Mod #1	Standard	.05	1.14	369	.37	23.9
2-7-80	80-1478	Hot LA-4	Stand.	Standard	.04	.67	368	.43	24.0
2-7-80	80-1480	Hot LA-4	Mod #2	Standard	.09	3.58	367	.33	23.8
2-22-80	80-1543	Hot LA-4	Stand.	Coupled	.07	1.63	385	.35	22.9
2-22-80	80-1544	Hot LA-4	Mod #2	Coupled	.18	10.51	376	.26	22.6
2-22-80	80-1545	Hot LA-4	Stand.	Coupled	.07	1.85	385	.35	22.8
2-22-80	80-1546	Hot LA-4	Mod #2	Coupled	.16	8.64	378	.25	22.6
1975 Nova with ER 78 x 14 radial tires, 12.0 hp, 4000 lb. inertia weight									
*2-22-80	80-1365	FTP	Baseline	Standard	.66	2.34	697	1.31	12.6
*2-26-80	80-1367	FTP	Baseline	Standard	.60	2.08	704	1.37	12.5
*3-01-80	80-1796	FTP	Mod #2	Coupled	1.43	23.44	721	1.49	11.6**

Note: Acceleration type standard is LA-4 cycle prescribed for the FTP.
Mod. #1 modifies the LA-4 cycle by using slightly greater acceleration rates at speeds below 25 mph.
Mod. #2 modifies the LA-4 cycle by using much greater acceleration rates at speeds below 25 mph.

*Results questionable see preceding text

**Because the baseline runs for the Nova were run with standard dynamometer rolls and the Mod #2 was run with coupled rolls, the data are not directly comparable. The coupled roll configuration causes a fuel economy penalty of approximately 5% which yields an actual fuel economy difference, attributable to the Mod #2 cycle, of about 3% for the Nova.

Appendix C
Acceleration Rate vs. Fuel Economy Test

Since the Gastell and modified cycle test programs (Appendix A and B) showed little effect on emissions or fuel economy, EPA undertook a small test program to further investigate the fuel economy effects of reduced acceleration.

A test program was devised consisting predominately of accelerations. The test cycles used a sequence of accelerations to a cruise speed, cruise for a few seconds, and then deceleration at a fixed, moderate rate. The cruise times were chosen so that all tests to a selected cruise speed would be of equal distance. This sequence was repeated 4 times (5 total cycles). The cycle was run for each combination of acceleration rate and final cruise speed.

A similar sequence between two vehicle speeds was performed to evaluate passing manuever fuel economy. As a control, vehicles were also tested several times for steady state fuel economy.

The testing was performed in randomized order to minimize any systematic test effects (see Acceleration Rate vs. Fuel Economy test sequence). A fuel flowmeter was used to measure fuel consumed (no gaseous emission data was taken). The dynamometer rolls were coupled together to minimize tire slippage.

The maximum and minimum acceleration rates were chosen to bracket the acceleration rates most current vehicles are capable of achieving.

The complete test matrix was:

MPH	Acceleration rate				
	1	2	3.3	4	5
0-35	x	x	x	x	x
0-45	x	x	x	@	@
20-35	x	x	x	x	x
30-45	x	x	x	@	@

@ Most vehicles unable to follow the driving traces at this acceleration rate/speed combination.

A 1980 Chevrolet Citation, 1980 Dodge Aspen, 1979 Ford Pinto, 1979 Mercury Zephyr, and a 1979 Oldsmobile Cutlass were used in this acceleration test program. A description of these vehicles is given in Table C-I. Each vehicle was checked for agreement with manufacturer's specifications and inspected. All vehicles were in satisfactory condition.

Tabel C-I
Phase 3 Acceleration kate vs. Fuel Economy Testing
Test Vehicle Description

	1980 Chevrolet Citation	1980 Dodge Aspen	1979 Ford Pinto	1979 Mercury Zephyr	1979 Oldsmobile Cutlass
Vehicle ID	1X687AW119256	NE29CAB11858B	9T11Y186165	9E35F621630	3R47A9M523280
Engine					
Type	V-6	Inline 6	Inline 4	V-8	V-6
Displacement	2.8 Liter	225 CID	140 CID	302 CID	3.8 Liter
Carburetor	2 Venturi	1 Venturi	1 Venturi	1 Venturi	2 Venturi
Transmission	3 Speed Automatic	3 Speed Lockup Automatic	3 Speed Automatic	3 Speed Automatic	3 Speed Automatic
Test Weight	3000 lb	4000 lb	3000 lb	3500 lb	4000 lb
Dynamometer HP	10.3 hp	12.0 hp	10.3 hp	11.2	12.0
Tire Type	Radial	BIAS	BIAS	Radial	Radial
Tire Size	P185/80R13	D78x14	B78x13	CR78x14	P195R/75
Emission Control	EGR	EGR	EGR	EGR	EGR
	Air Pump	Pulsating Air	Pulsating Air	Air Pump	Air Pump
	Oxidation Catalyst	Oxidation Catalyst	Oxidation Catalyst	Oxidation Catalyst	Oxidation Catalyst

Appendix C
Acceleration Rate vs. Fuel Economy
Test Sequence

Fuel Economy Sample	Speed	Comments
	50 mph	initial vehicle warm up for 30 minutes
	35 mph	warm up for 2 minutes
X	35 mph	steady state fuel economy for 103 seconds
	0 mph	idle (drive) for 30 seconds
X	0-35 mph	accelerations at 1 mph/sec.
	0 mph	idle (drive) for 30 seconds
X	0-35 mph	accelerations at 4 mph/sec.
	35 mph	warm up for 2 minutes
X	35 mph	steady state fuel economy for 103 seconds
	0 mph	idle (drive) for 30 seconds
X	0-35 mph	acceleration @ 3.3 mph/sec.
	0 mph	idle (drive) for 30 seconds
X	0-35 mph	acceleration @ 2 mph/sec.
	0 mph	idle (drive) for 30 second
X	0-35 mph	accelerations @ 5mph/sec.
	0 mph	idle (drive) for 30 seconds
	35 mph	warm up for 2 minutes
X	35 mph	steady state fuel economy for 103 seconds
	0 mph	idle (drive) for 1 minute
X	0 mph	idle (drive) fuel consumption for 3 minutes
	45 mph	warm up for 2 minutes
X	45 mph	steady state fuel economy for 80 seconds
	0 mph	idle (drive) for 30 seconds
X	0-45 mph	accelerations @ 1 mph/sec.
	0 mph	idle (drive) for 30 seconds
X	0-45 mph	accelerations @ 3.3 mph/sec.
	0 mph	idle (drive) for 30 seconds
X	0-45 mph	accelerations @ 2 mph/sec.
	0 mph	idle (drive) for 30 seconds
	45 mph	warm up for 2 minutes
X	45 mph	steady state fuel economy for 80 s nds
	0 mph	idle (drive) for 30 seconds
	20 mph	warm up for 2 minutes
X	20 mph	steady state fuel economy f tes
	35 mph	warm up for 2 minutes
X	35 mph	steady state fuel economy f 103 seconds
	20 mph	warm up for 2 minutes
X	20-35 mph	accelerations @ 1 mph/sec.
	20 mph	warm up for 30 seconds
X	20-35 mph	accelerations @ 4 mph/sec.
	20 mph	warm up for 30 seconds
X	20-35 mph	accelerations @ 3.3 mph/sec.
	20 mph	warm up for 30 seconds
X	20-35 mph	accelerations @ 2 mph/sec.
	20 mph	warm up for 30 seconds

X	20-35 mph	acceleration @ 5 mph/sec.
	20 mph	warm up for 2 minutes
X	20 mph	fuel economy for 3 minutes
	35 mph	warm up for 2 minutes
X	35 mph	fuel economy fo 103 seconds
	0 mph	idle (drive) for 1 minute
X	0 mph	idle (drive) fuel consumption for 3 minutes
	30 mph	warm up for 2 minutes
X	30 mph	fuel economy for 2 minutes
	45 mph	warm up for 2 minutes
X	45 mph	fuel economy for 80 seconds
	30 mph	warm up for 2 minutes
X	30-45 mph	accelerations @ 1 mph/sec.
	30 mph	warm up for 2 minutes
X	30-45 mph	accelerations @ 3.3 mph/sec.
	30 mph	warm up for 30 seconds
X	30-45 mph	accelerations @ 2 mph/sec.
	30 mph	warm up for 2 minutes
X	30 mph	fuel economy for 2 minutes
	45 mph	warm up for 2 minutes
X	45 mph	fuel economy for 80 seconds.

Table C-II
Acceleration Rate Fuel Economy
miles per gallon

	Chevrolet Citation 2.8 liter	Dodge Aspen 225 CID	Ford Pinto 140 CID	Mercury Zephyr 302 CID	Oldsmobile Cutlass 3.8 liter
0-35 mph					
1 mph/sec.	19.3	16.8	21.8	16.0	17.4
2 mph/sec.	19.7	16.0	21.4	15.8	17.5
3.3 mph/sec.	19.4	15.6	20.4	15.3	16.9
4 mph/sec.	18.6	14.1	19.3	15.0	16.2
5 mph/sec.	18.2	14.3	19.1	14.7	15.2
0-45 mph					
1 mph/sec.	20.7	17.9	22.1	17.3	18.6
2 mph/sec.	20.4	16.1	21.6	16.9	17.9
3.3 mph/sec.	19.5	15.8	20.6	16.1	16.3
20-35 mph					
1 mph/sec.	25.0	22.3	27.3	20.1	21.8
2 mph/sec.	23.2	19.7	24.9	18.9	20.2
3.3 mph/sec.	22.4	18.0	23.6	18.3	18.9
4 mph/sec.	22.0	17.4	22.4	18.2	18.2
5 mph/sec.	20.8	17.3	22.6	17.9	18.4
30-45 mph					
1 mph/sec.	25.6	22.6	26.8	21.5	23.0
2 mph/sec.	23.1	20.0	25.1	19.6	20.9
3.3 mph/sec.	20.9	19.4	24.1	18.7	18.1

Table C-III
Acceleration Rate Fuel Economy
Percentage Improvement from Highest Acceleration
Rate to 1 mph/sec. Acceleration Rate

	Chevrolet Citation 2.8 liter	Dodge Aspen 225 CID	Ford Pinto 140 CID	Mercury Zephyr 302 CID	Oldsmobile Cutlass 3.8 liter
0-35 mph	6.0%	17.5%	14.1%	8.8%	14.4%
0-45 mph	6.1%	13.3%	7.3%	7.5%	14.1%
20-35 mph	20.1%	28.9%	20.8%	12.3%	18.5%
30-45 mph	22.5%	16.5%	11.2%	15.0%	27.1%

combined average for all vehicles is 14.6%

Table C-IV

Percentage Rate Fuel Economy
Percentage Improvement from Highest Acceleration
Rate to 2 mph/sec. Acceleration Rate

	Chevrolet Citation 2.8 liter	Dodge Aspen 225 CID	Ford Pinto 140 CID	Mercury Zephyr 302 CID	Oldsmobile Cutlass 3.8 liter
0-35 mph	8.2%	11.8%	12.0%	7.5%	15.1%
0-45 mph	4.6%	1.9%	4.9%	5.0%	9.8%
20-35 mph	11.5%	13.9%	10.2%	5.6%	9.8%
30-45 mph	10.5%	3.1%	4.6%	4.8%	15.5%

combined average for all vehicles is 8.5%

Table C-V

Cruise Fuel Economy
miles per gallon

Cruise Speed-mph	Chevrolet Citation 2.8 liter	Dodge Aspen 225 CID	Ford Pinto 140 CID	Mercury Zephyr 302 CID	Oldsmobile Cutlass 3.8 liter
Idle (drive)*	.35	.56	.31	.76	.45
20	30.8	33.5	35.5	26.2	36.4
30	32.2	36.0	35.0	28.0	37.1
35	32.6	35.3	35.3	28.0	34.3
45	30.7	31.0	33.3	26.9	30.4

*Idle fuel consumption is expressed in gallons per hour

FUEL ECONOMY VS ACCELERATION
0-35 MPH ACCELERATIONS

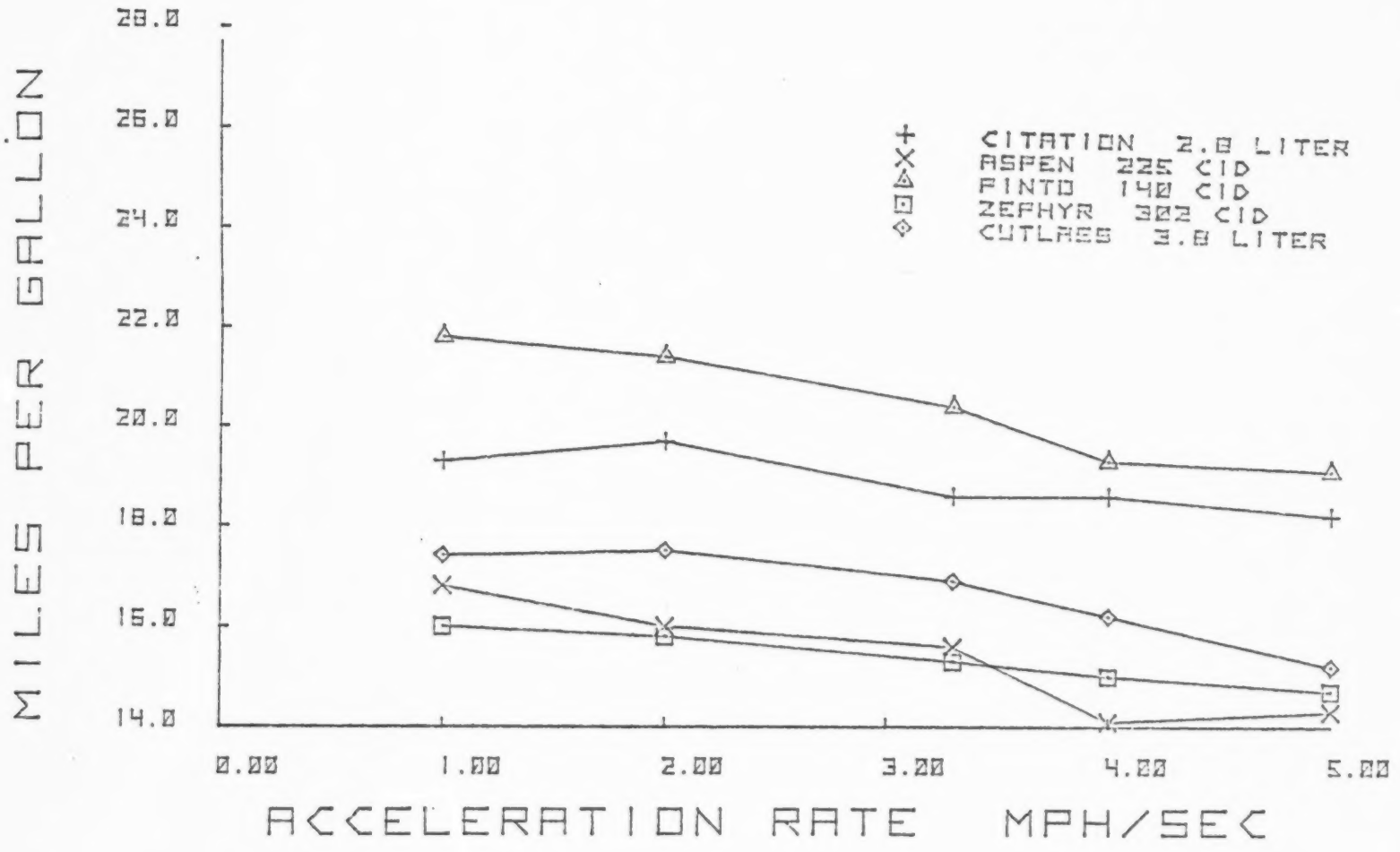


Figure C-1

FUEL ECONOMY VS ACCELERATION
0-45 MPH ACCELERATIONS

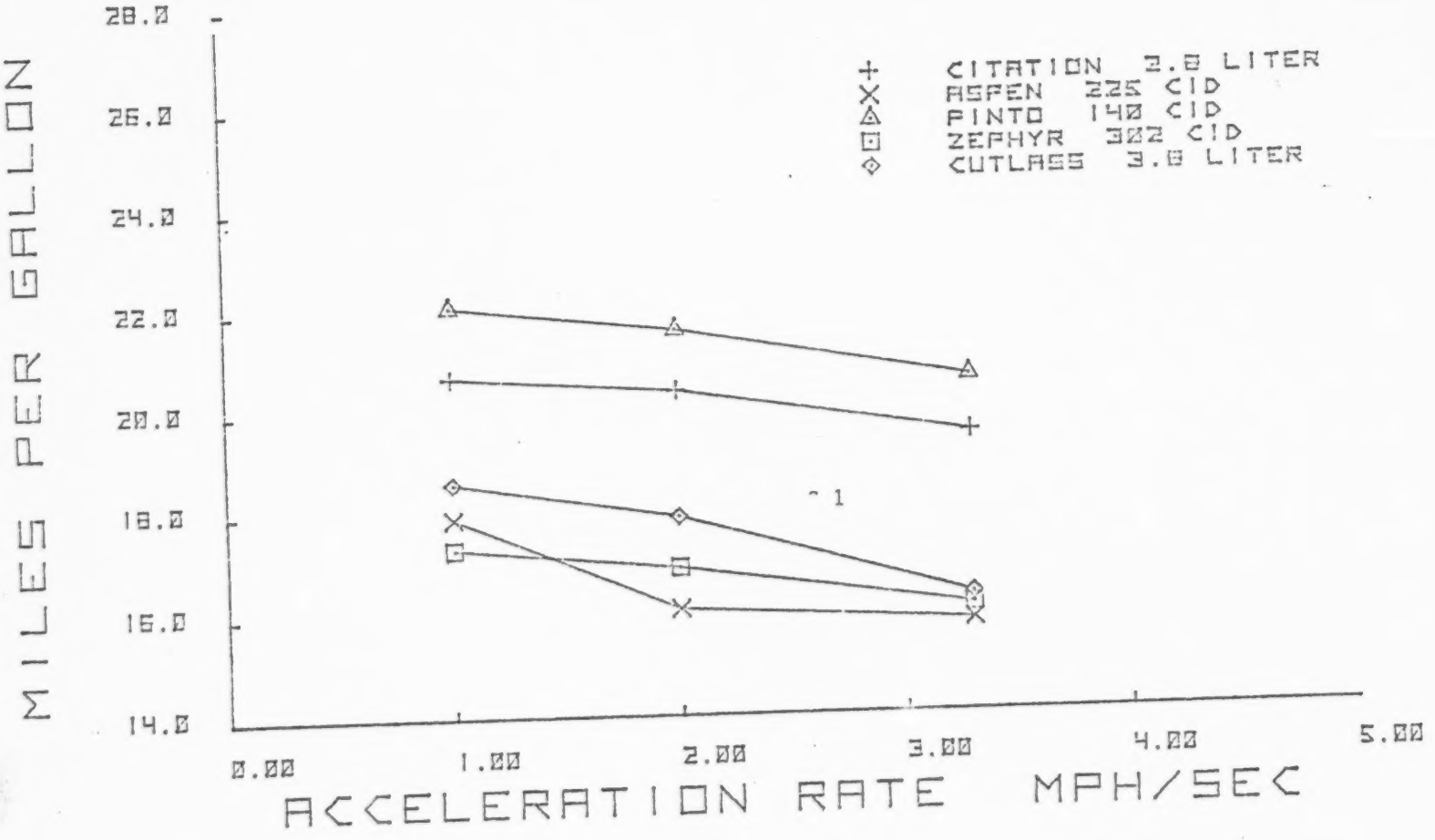


Figure C-2

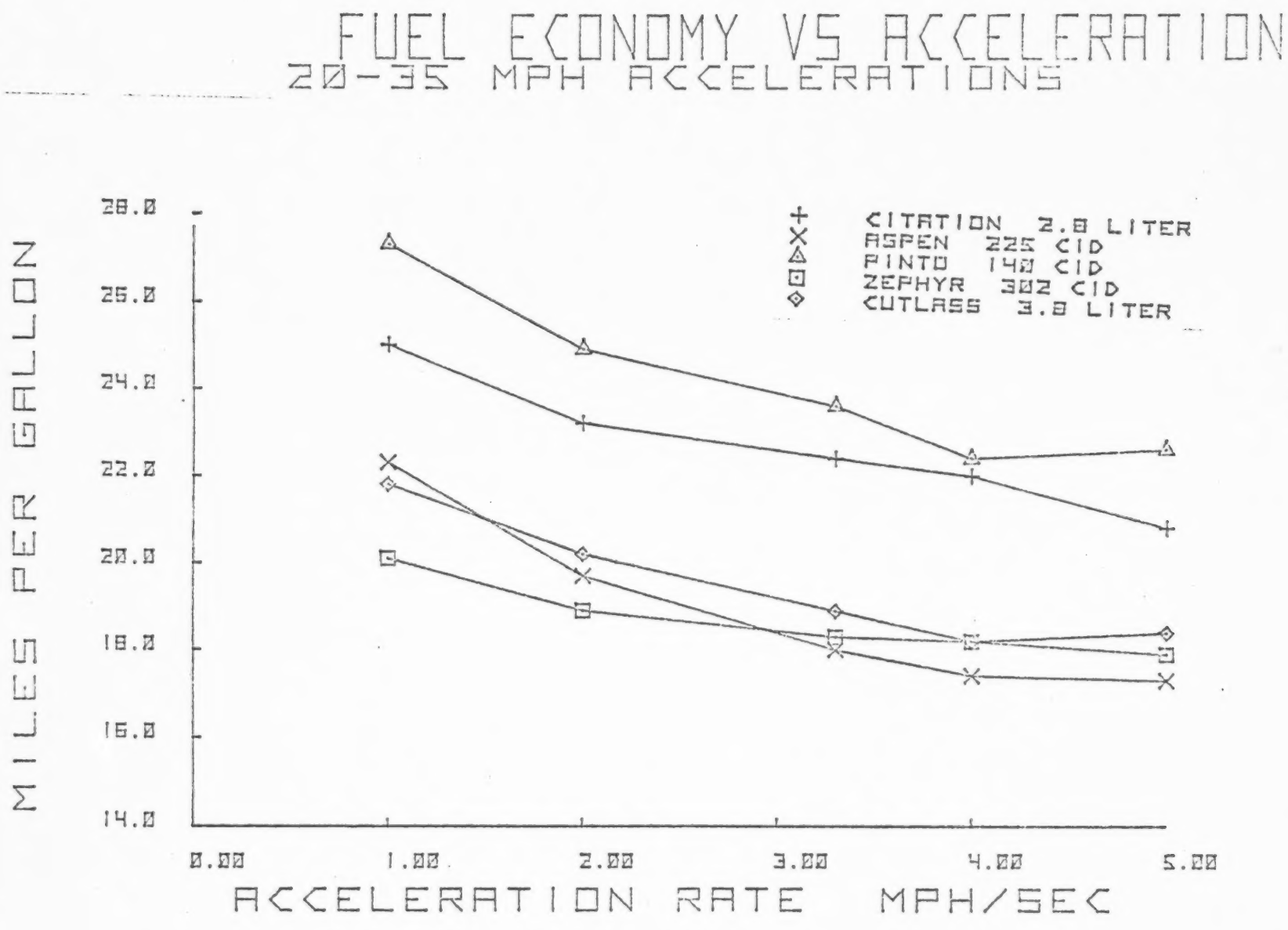

FUEL ECONOMY VS ACCELERATION
20-35 MPH ACCELERATIONS
MILES PER GALLON
28.0
26.0
24.0
22.0
20.0
18.0
16.0
14.0
0.00
1.00
2.00
3.00
4.00
5.00
ACCELERATION RATE MPH/SEC
CITATION 2.8 LITER
ASPEN 225 CID
PINTO 140 CID
ZEPHYR 302 CID
CUTLASS 3.8 LITER

Figure C-3

FUEL ECONOMY VS ACCELERATION
30-45 MPH ACCELERATIONS

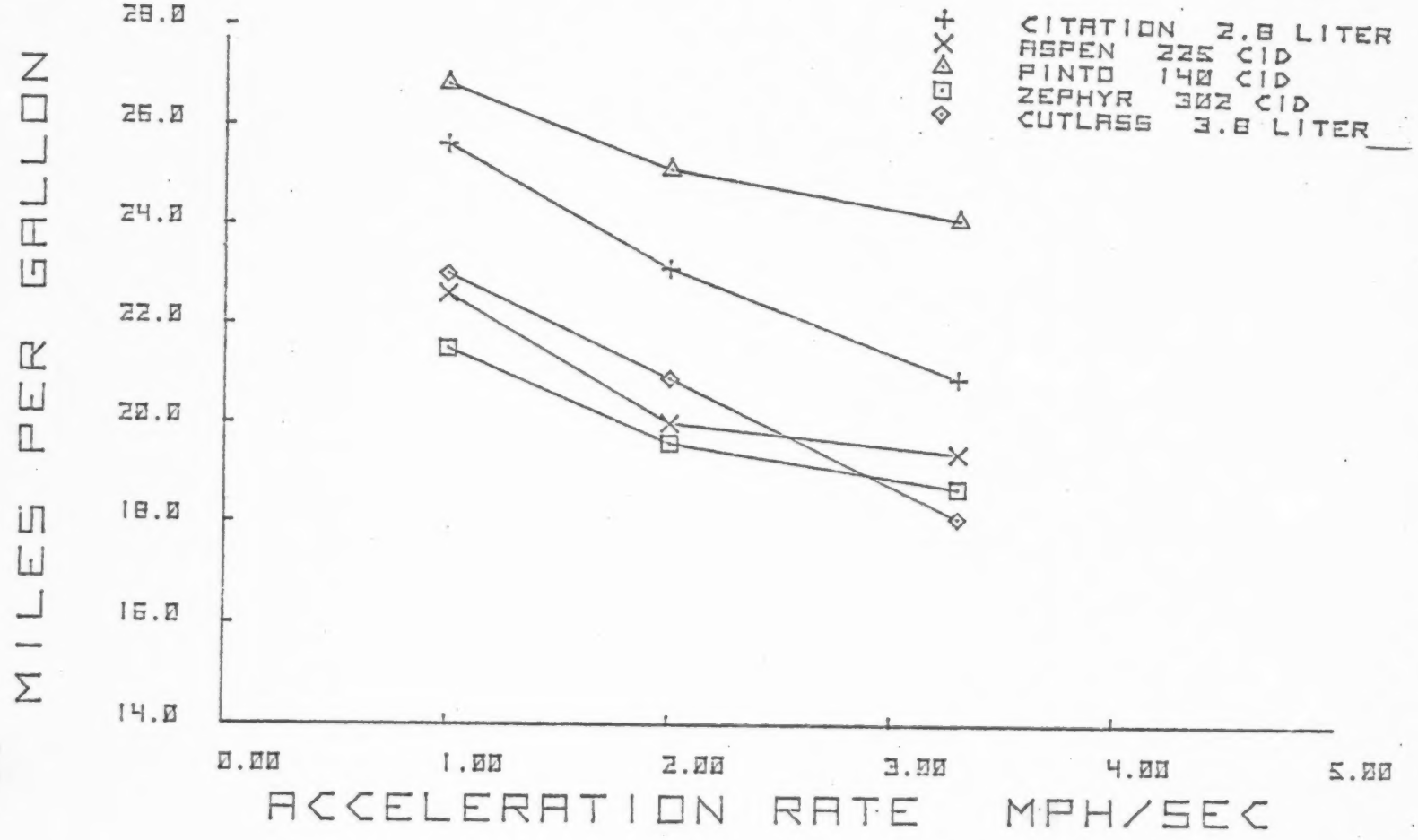


Figure C-4

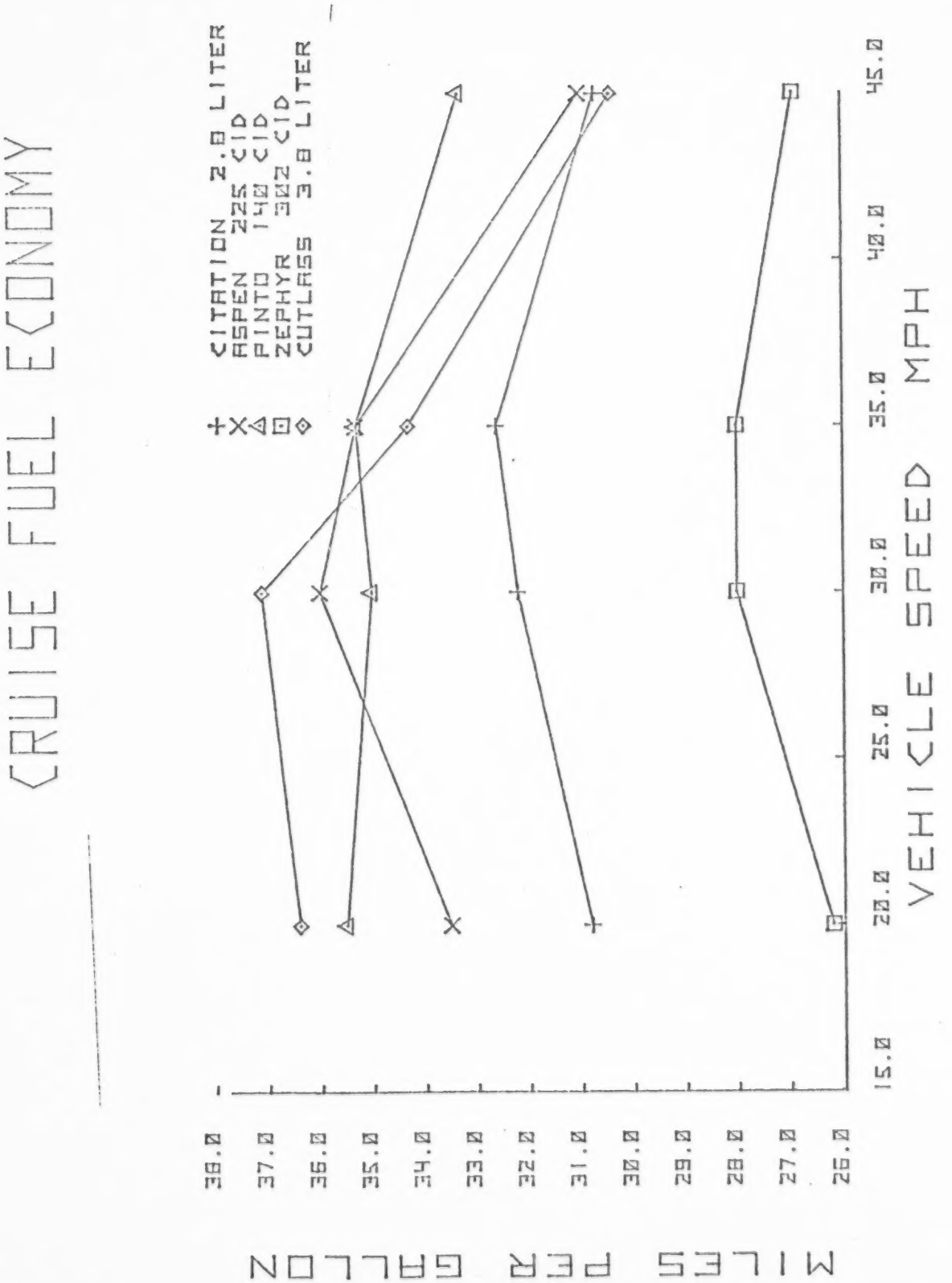

CRUISE FUEL ECONOMY
CITATION 2.8 LITER
ASPEN 225 CID
PINTO 140 CID
ZEPHYR 302 CID
CUTLASS 3.8 LITER
MILES PER GALLON
39.0
37.0
36.0
35.0
34.0
33.0
32.0
31.0
30.0
29.0
28.0
27.0
26.0
15.0
20.0
25.0
30.0
35.0
40.0
45.0
VEHICLE SPEED MPH

Figure C-5

Appendix D
Road Testing with the Gastell Device

SAN ANTONIO ROAD ROUTE TEST PROCEDURE

A. The general procedure is as follows:

1. Drive test vehicle from Southwest Research Institute to Layover Point.

2. Start Vehicle

3. Start Fluidyne Recorder, wait 60 seconds. Then drive road course. Use normal driving techniques.

4. Return to Layover Point, shift into park, idle for 60 seconds. At 60 secs, stop Fluidyne totalizer and hit print button. Record fuel and temperature readings on work sheet.

5. Shut engine off, zero and start Fluidyne timer.

6. At 500 seconds, start vehicle using hot start procedure.

7. At 560 seconds shift into drive and drive road course using normal driving technique. (Go to Step 4 - repeat as many times as possible before 3:00 p.m.).

Note: The Mercury Marquis was run with 60 second layovers instead of 500 seconds.

B. General Test Requirements

1. The first test run of each day was considered warm up and the data was not used in any subsequent calculations.

2. Only tests run between 9:00 a.m. and 3:00 p.m. were used due to San Antonio traffic considerations.

3. Only tests run on weekdays, Monday through Friday, were used due to San Antonio traffic considerations.

4. Temperature, humidity, barometer, wind speed and direction were taken at 9:00 a.m. and 3:00 p.m.

5. All test fuel was from a single batch of Gulfpride unleaded fuel provided by Southwest designated EM-356.

6. All test vehicle fuel tanks were drained prior to start of testing to avoid fuel mixing.

7. All vehicles were specification checked and examined for proper vacuum line routing and evidence of tampering.

8. The Chevrolet Citation and Nova were extensively checked out to manufacturers specifications at the EPA-MVEL prior to being driven to San Antonio.

9. Fuel Tanks on each vehicle were filled with EM-356 fuel each morning. Vehicles used about 1/4 tank each testing day.

10. Tire pressure of all test vehicle tires was checked and set to manufacturer's specifications each morning prior to leaving Southwest Research.

11. Test runs with abnormal time, fuel consumption, or circumstances were deleted from consideration. Examples of such circumstances were funeral processions (3 occurences) and could not exit highway due to traffic (1 time).

12. In all test days where the Gastell Device was to be used, the device calibration was checked prior to leaving Southwest using the following procedure.

    An 8" diameter pressure gauge that was previously checked versus a mercury manometer in Ann Arbor was attached to a hand vacuum pump which was then connected to the device. Ray Smith of Gastell had transmitted the following device specifications:

	ON	OFF
4 cylinder vehicles	3.5" Hg	4.5" Hg
6 cylinder vehicles	5.0" Hg	6" Hg
8 cylinder vehicles	7.0" Hg	8"Hg

    The devices did not need calibration until the setpoints were modified on the Nova. The calibration checks of the 8 cylinder devices were about on at 7.0" Hg. Since these devices were submitted by Ray Smith with the 511 Application for evaluation and the specifications given in the application only specified the ON set point, the devices were deemed acceptable.

13. Testing run when the pavement was wet was not used in the analysis. When pavement was damp the results were used if they appeared in-line with other measurements.

14. A minimum of 5 tests were run with most vehicles to familiarize the driver with the vehicle and route. Data was not collected during driver familarization.

15. The fuel totalizer display was located in the vehicle so that the driver could not see the display while driving.

16. The Fluidyne flowmeters were calibrated in July, 1980 and checked for calibration in December 1980.

Table D-1
Phase 4 Gastell Road Testing
Test Vehicle Description

	1980 Citation	1975 Chevrolet Nova	1980 Mercury Cougar XR-7	1979 Mercury Marquis
Vehicle ID	1X685AW15057	1X27L5L115735	0H93D626537	9Z6ZH619190
Engine				
type	inline, 4 cylinder	V-8	V-8	V-8
Displacement	2.5 liters	350 CID	255 CID	351
Carburetor	2 venturi	4 venturi	2 venturi	2 venturi
Transmission	3 speed automatic	3 speed automatic	3 speed automatic	3 speed automatic
axle ratio	2.53	3.08	2.50	2.30
Tire Type	radial	radial	radial	radial
Tire Size	P185xR13	ER78x14	P195/75R14	GR78x14
Emission Control	EGR closed loop 3 way catalyst	air injection pump oxidation catalyst	EGR oxidation catalyst	air injection oxidation catalyst

San Antonio Road Route

Number of Stop Signs: 0
Number of Stop Lights: 28
Average Distance: 7.2 miles
Average Speed: 19.6 mph
Maximum Speed: 55 mph
Stops/Mile: 3.9

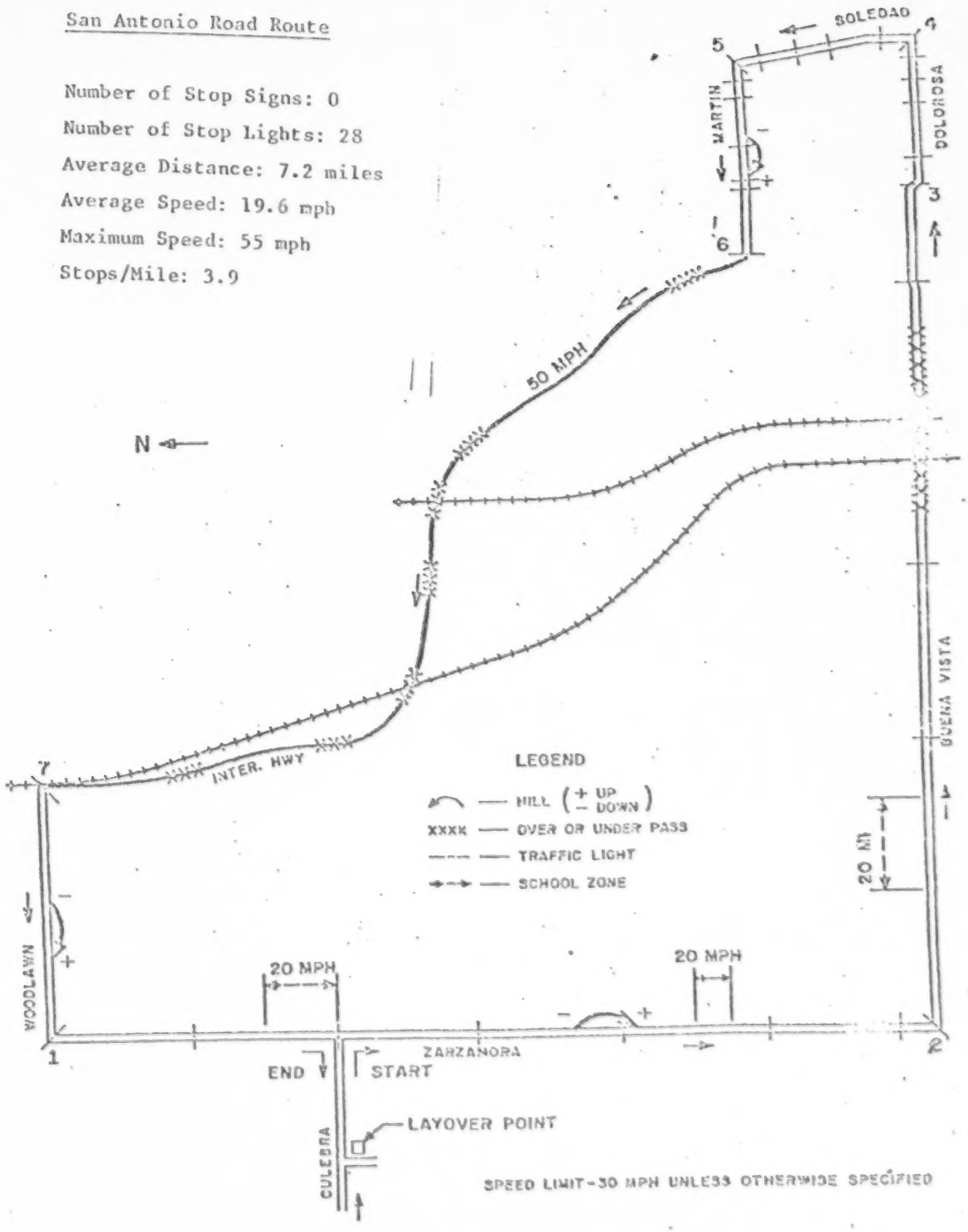


Figure D-1 San Antonio Road Route

Attachment C

UNITED STATES DEPARTMENT OF COMMERCE
National Bureau of Standards
Washington, D.C. 20234

October 29, 1979

Mr. Ray P. Smith, Jr.
P.O. Box 294
Williamsport, PA 17701

Dear Mr. Smith:

We have completed evaluation of your invention entitled "Gastell" which you submitted for evaluation in accordance with Section 14 of the Federal Nonnuclear Energy Research and Development Act of 1974.

Your invention is a manifold vacuum monitoring device that signals inefficient vehicle operation by both manual and audible indicators.

Manifold vacuum is a recognized reliable measure for indicating engine operating efficiency. Devices to enable drivers to make beneficial use of the measure have been, as you know, on the market for a long time. Such devices can certainly be of significant value in enabling motivated drivers to reduce fuel usage by increasing operating efficiency.

We wish to encourage use of engine efficiency indicators as a means to reduce automotive fuel consumption. While there have been recent warnings by such Federal agencies as the Federal Trade Commission, against use of automotive devices which purport to save energy, devices such as yours should not be included in the warned-against class.

Your particular device is seen to have special value in view of the audible signaling feature. Nevertheless, this engineering improvement does not constitute new technology of the type appropriate for support under this program. We regret, therefore, we are unable to justify a recommendation to the Department of Energy.

While "Gastell" does not qualify for support under this program, you may wish to contact the Small Business Administration (SBA) for assistance under their loan or other programs. A district office of the SBA is located at:

Penn Place
20 N. Pennsylvania Avenue
Wilkes-Barre, PA 18702
(717) 826-6497

If you do contact the SBA, this letter will attest to our opinion that your device is technically sound and commercially competitive, and that its installation and use in automobiles can lead to significant fuel savings by the drivers of such vehicles.

We wish you success in your marketing efforts. Thank you for your interest in our program.

Sincerely,

George P. Lewett
Chief, Office of Energy-Related Inventions